United States Department of Agriculture
Research, Education and Economics

ARS ❑ CSREES ❑ ERS ❑ NASS
Manual

Title: ARS Construction Project Design Standard

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This MANUAL provides the basic Agency design criteria and design quality standards for the construction, repair, and alteration of ARS buildings and facilities.

1. REFERENCE

For objective and policy of ARS Construction Project Design Standard, see DIRECTIVE 242.1.

2. ABBREVIATIONS

- A-E - Contract Architect-Engineers
- CO - Contracting Officer
- EPM - Engineering Project Manager

3. ORGANIZATION OF MANUAL

This MANUAL is organized and presented according to the following outline:

CHAPTER 1 - BASIC REQUIREMENTS

This chapter addresses design compliance with codes and regulations, design principles covering environmental and functional needs, safety, health and security, economy, conservation of resources, and historical preservation.

CHAPTER 2 - SITE PLANNING AND LANDSCAPE DESIGN

This chapter addresses requirements considering physical character of the site, grading and drainage, pedestrian and vehicular circulation, and planting.

CHAPTER 3 - ARCHITECTURAL ELEMENTS

This chapter addresses space requirements and handicap accessibility, exterior and interior building components and finishes, and support service areas.

CHAPTER 4 - STRUCTURAL AND GEOTECHNICAL ENGINEERING

This chapter addresses the building structural elements including requirements for foundation, substructure and superstructure, and equipment support system design.

CHAPTER 5 - MECHANICAL

This chapter addresses requirements and design considerations for plumbing, heating, ventilation and air-conditioning (HVAC), and underground heat distribution system.

CHAPTER 6 - ELECTRICAL

This chapter addresses the requirements and design considerations for primary/secondary services and distribution, emergency power, illumination, special equipment, and communication and signaling systems.

CHAPTER 7 - SAFETY AND HEALTH ELEMENTS

This chapter addresses the requirements and design considerations related to laboratory ventilation, hazardous material storage, emergency egress requirements, and asbestos abatement.

CHAPTER 8 - ELEVATORS (VERTICAL TRANSPORTATION SYSTEM)

This chapter addresses the requirements and design considerations covering passenger elevators, freight elevators, dumbwaiters, and wheelchair lifts.

CHAPTER 9 - BIOHAZARD CONTAINMENT DESIGN

This chapter addresses requirements and design considerations for containment facility covering hazard classification and choice of containment, architectural, mechanical and electrical design features, testing and certification requirements for critical components of containment system, and bid document preparation.

CHAPTER 10 - ANIMAL RESEARCH AND CARE FACILITIES

This chapter addresses requirements and design considerations for animal welfare and special facility features.

CHAPTER 11 - GREENHOUSE DESIGN GUIDE

This chapter addresses requirements and design considerations for greenhouse design covering sitework, architectural and structural requirements, mechanical system design, control requirements for HVAC systems, irrigation systems, and electrical.

CHAPTER 12 - DRAFTING STANDARDS

This chapter provides a standard for producing clear, uniform design drawings and illustrations.

T. J. CLARK
Deputy Administrator
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EXHIBIT
1 Construction Project Design Standard

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CHAPTER 1. BASIC REQUIREMENTS
PART 1. GENERAL

1.1.1 Purpose: This MANUAL establishes the basic ARS design criteria for the construction, repair, and alteration of ARS building and facilities. The MANUAL is intended for the use of ARS technical and other personnel and professional services contractors involved in design, design programming, and design review.

1.1.2 Compliance with National Model Codes and Standards:

a. The project design for the construction or alteration of ARS buildings and facilities shall be developed, to the maximum extent feasible, in compliance with one of the nationally recognized model building codes and with other applicable nationally recognized codes and standards. Such model codes and other standards shall include but not be limited to those listed in Table 1-1.

b. In addition to using the applicable national model codes as a minimum standard; special requirements directly related to local practices or circumstances, which do not compromise the best interest of the Government shall be incorporated into project design. Considerations shall be given for incorporating the requirements (other than procedural requirements) of zoning laws and laws relating to landscaping, open space, minimum distance of a building from the property line, maximum height of a building, historic preservation, esthetic qualities of a building, and other similar laws of a state or a political subdivision of a state which would apply to the building if it were not a building constructed or altered by the Federal Government.

c. The project design shall meet all applicable Federal, State, and local regulations for preventing, abating, controlling air and water pollution, and controlling radiation and noise.

d. Any conflict or deviations from the model codes resulting from special requirements directly related to local practices, State or Federal regulations including ARS technical requirements contained in this MANUAL, shall be resolved by designing for the most stringent requirement. The A-E is expected to research all applicable codes, standards, and regulations to determine the scope of regulatory compliance required by the project at hand.

TABLE 1-1 - Example Model Codes and Standards

Building Codes	**Publisher***
Basic/National Building Code	BOCA
Standard Building Code	SBCC
Uniform Building Code	ICBO
One- and Two- Family Dwelling Code	CABO
Mechanical Codes	
Basic Mechanical Code	BOCA
Standard Mechanical Code	SBCC
Uniform Mechanical Code	ICBO
Plumbing Codes	
Basic Plumbing Code	BOCA
ICBO Plumbing Code	ICBO
Standard Plumbing Code	SBCC
Uniform Plumbing Code	IAMPO
Fire Codes	
Basic Fire Prevention Code	BOCA
Fire Prevention Code	NFPA
National Fire Codes	NFPA
Standards Fire Prevention Code	SBCC
Uniform Fire Code	ICBO
Energy Conservation Codes	
Model Energy Code	CABO
Electrical Codes	
National Electrical Code	NFPA
Gas Codes	
National Fuel Gas Codes	NFPA
Standard Gas Code	SBCC
Sign Codes	
Uniform Sign Code	ICBO
Miscellaneous Standards	
ANSI Standards Catalogue	ANSI
ASTM Standards Catalogue	ASTM
NFPA Codes and Standards Catalogue	NFPA
NFPA 101/Life Safety Code	NFPA
Standard Building Code Book of Standards	SBCC
Uniform Building Code Book of Standards	ICBO

*ANSI = American National Standards Institute; ASTM = American Society for Testing and Materials; BOCA = Building Officials and Code Administrators; CABO = Council of American Building Officials; ICBO = International Conference of Building Officials; IAMPO = International Association of Plumbing and Mechanical Officials; NFPA = National Fire Protection Association; SBCCI = Southern Building Code Congress International.

1.1.3 Determining Regulatory Requirements:

The most effective way to deal with code compliance is for the A-E to meet with local officials prior to schematic design to determine the regulatory requirements for the particular building in question. These officials often include the responsible building official and the Fire Marshall. In small communities the duties of these two officials may be carried out by the same person.

During the initial meeting, notes made by the A-E may prove helpful. Items not discussed in this meeting may not comply with the code. The A-E, therefore, should not expect a full code review at the preliminary session where general code issues are discussed.

Early input by regulatory officials is necessary to eliminate potential costly design changes later in the project.

Once the regulatory requirements have been identified, the A-E can proceed with design and develop the documents necessary for a building department plan review as a prerequisite to obtaining a building permit.

1.1.4 Metrication Policy of Agricultural Research Service.

The Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418, Section 5164) declares the metric system as the preferred measurement system for U.S. trade and commerce. The law requires that each Federal agency, by a date certain and to the extent economically feasible by the end of the fiscal year 1992, use the metric system of measurement in its procurements, grants, and other business-related activities, except to the extent such use is impractical or is likely to cause significant inefficiencies or loss of markets to United States firms, such as when foreign competitors are producing competing products in non-metric units.

It is ARS policy to comply where practical with the implementation of metrication under the following conditions when preparing design documents:

a. **When metric is clearly the accepted industry measurement system,** the A-E shall incorporate the use of metric system in developing contract specifications, drawings, and other measurement sensitive documentation.

b. **When it is known that metric is not fully incorporated into the industry system as a standard practice of measurement,** the A-E shall incorporate the use of any of the following measurement systems (as directed by the Engineering Project Manager) in developing contract specifications, drawings, and other measurement sensitive documentation.

1. Traditional inch-pound measurement system.

2. "Soft metric" (the result of mathematically converting inch-pound measurements to metric equivalents).

3. "Hybrid" systems (e.g., systems which use inch-pound measurements for some parts of an item and metric measurements for other parts).

4. "Dual" systems (e.g., where an item is produced and described in inch-pound values, but is also described in soft metric values for informational or comparison purposes).

1.1.5 ARS Energy Management Policy for Buildings and Facilities.

Consistent with the requirements defined by Public Law 100-615 "The Federal Energy Management Improvement Act of 1988" and Executive Order on Federal Energy Management (E.O. 12759), it is ARS policy to conserve and make more efficient use of energy in ARS buildings and facilities **through** improved operations and maintenance, the use of new energy efficient technologies, and the application and achievement of energy efficient design and construction. It is ARS' goal to achieve optimum energy efficiency (while maintaining a high level of employee safety and health) by:

a. Reducing the overall energy use in ARS buildings and facilities, on a BTU per gross square foot basis, by 10 percent between 1985 and 1995 to the extent that the energy efficiency measures minimize life cycle costs and are cost-effective in accordance with 10 CFR Part 436.

b. Reducing the overall energy use in ARS buildings and facilities, on a BTU per gross square foot basis, taking into account utilization, by 20 percent between 1985 and 2000 to the extent that the energy efficiency measures minimize life cycle costs and are cost-effective in accordance with 10

CFR Part 436.

c. Increasing energy efficiency in ARS industrial type facilities in the aggregate by 20 percent between 1985 and 2000, to the extent that the energy efficiency measures minimize life cycle costs and are cost-effective in accordance with 10 CFR Part 436.

d. Minimizing the use of petroleum products for facilities operations or building purposes **through** 1) switching to an alternative energy source if it is estimated to minimize life cycle costs and which will not violate Federal, State, or local clean air standards; and 2) modifying existing systems where potential for dual fuel capability exists and where practicable.

e. Assuring the purchase of energy efficient goods and products by selecting for procurement those energy consuming goods or products which are the most life cycle cost-effective, pursuant to the requirements of the **Federal Acquisition Regulation.** To the extent practicable, requiring vendors to provide appropriate data that can be used to assess the life cycle costs of the goods or products, including building energy system components, lighting systems, office equipment, and other energy using equipment.

f. Participating in demand-side management services such as rebates and shared energy savings contracts.

g. Implementing the applicable rules and regulations regarding Federal property and energy management for current building space.

h. Complying with the energy performance standards as set forth in 10 CFR Part 435 in the design and construction of new ARS buildings and facilities.

In order to achieve ARS goal for optimum energy efficiency, the A-E shall adopt such procedures as may be necessary to ensure that the design of new or the renovation of existing ARS buildings and facilities be undertaken in a manner that provides for appropriate consideration of the principles of effective energy building design and the compliance requirements prescribed in 10 CFR Part 435.

PART 2. DESIGN PRINCIPLES

1.2.1 General Policy. ARS buildings shall be designed and alterations made to best meet the functional, safety, and environmental needs of the programs they house.

1.2.2 Environmental and functional needs. ARS buildings shall provide an environment in which occupants can do their work with maximum efficiency at the optimum level of comfort, taking the following factors into consideration:

a. **Arrangement of space.** Space relationships within buildings shall be planned to optimize the functions being performed by the occupant. Interaction areas shall be provided within the building to promote informal technical discussion between scientists.

b. **Barrier-free access.** Buildings shall meet the needs of individuals with physical disabilities. Design shall conform to the requirements as outlined in the Uniform Federal Accessibility Standards. To the extent resources permit, designs shall extend beyond the minimum barrier-free design required by Federal law and regulation.

c. **Illumination.** Natural and artificial illumination shall be sufficient to meet requirements of the tasks performed by the occupants.

d. **Thermal environment.** The thermal environment shall be such as to provide healthy working conditions for the occupants and proper climatic conditions for the work being performed. Provision of flexibility and suitable control is necessary.

e. **Acoustical environment.** New buildings and alterations shall be planned and designed to minimize noise that disturbs occupants unduly or interferes with their ability to do their work. An adequate level of privacy shall be provided so that occupants can perform their tasks effectively with minimum outside disturbance. The level of privacy required will vary depending on the tasks involved.

f. **Maintenance and operation.** Designs shall be based on user needs and maintenance capabilities and shall satisfy the functional requirements for efficient operation of the facility. Materials and projects shall be durable, easily maintained, and appropriate for the intended use.

g. **Harmony with environment.** Special attention shall be paid to the arrangement of streets and public space of which the building is a part. Within budgetary and site limitations, designs shall include generous development of well-landscaped, inviting, people-oriented space.

h. **Regional character.** Buildings shall reflect the architectural character of the locale. Local building ordinances and zoning practices shall generally be followed. Use of materials and products indigenous to the locale of the project shall be given preference.

1.2.3 Safety, health and security. ARS buildings shall provide an environment that is safe and healthful for occupants, and that offers them maximum protection during emergencies or disasters.

a. **Structural adequacy.** Design of buildings shall be adequate for the functions to be performed and the loads imposed by building equipment, occupants, and their activities. Soil and other geotechnical problems shall be carefully analyzed and resolved during the design process.

b. **Protection against disaster.** Design shall provide minimum exposure to fire, earthquake, or natural disaster, and shall provide barrier-free egress and refuge for all people, including the disabled, in an emergency.

c. **Security.** Buildings shall be designed to minimize security risk to persons, research animals, and property.

d. **Accident prevention design.** Design shall be the result of safety analyses and shall address unsafe conditions that cause injury, illness, or property damage.

e. **Health hazards.** Materials and products with known or suspected properties that are hazardous to the health of occupants and installers shall be avoided in designing buildings. Hazardous arrangements of building components shall be avoided.

f. **Repair, renovation, and alterations.** Design shall be accomplished for repair, renovation, and alteration activities to reduce or eliminate hazardous exposure of the occupants through selection and use of materials and methods.

1.2.4 Economy. ARS buildings shall be designed at the most reasonable cost in terms of combined initial and long-term expenditures, without compromising other project requirements.

a. **Site adaptation.** In many, if not most, instances, a site will already have been selected before design begins; however, design professionals shall, where possible, have a part in the selection. The design of the building shall be sited economically and efficiently.

b. **Efficient utilization.** Ratio of net usable to gross area shall be as high as possible consistent with program objectives. Space allocation for occupants shall be as low as possible consistent with

GSA guidelines and the intended functions.

c. **Economical materials.** Materials, products, and systems of proven dependability shall be used in the design or alteration of buildings. Materials shall be as economical as possible, in terms of combined initial and long-term cost, consistent with program objectives. To the extent possible, standard commercially available products shall be used.

d. **Cost alternatives.** Alternatives shall be considered to ensure long-term, cost effective design.

e. **Maintenance, operation, repair, and replacement costs.** Buildings shall be designed, and materials selected, to minimize the cost of maintenance and repair.

f. **Foster maximum competition in bidding.** Buildings shall be designed and building materials, components, and systems incorporated into the design so as to foster maximum competition among bidders, suppliers, and contractors.

g. **Project administration.** Projects shall be planned and scheduled to ensure effective and efficient design.

1.2.5 Conservation of resources. Energy conservation shall be given prime consideration in the design of buildings. Products, materials, and systems shall be selected with a view toward minimizing the use of nonrenewable resources.

1.2.6 Historical preservation. Special sensitivity shall be shown in altering and retrofitting ARS buildings of historical significance to preserve and highlight their architectural integrity. The improvement design shall make no major impact upon the qualities which make these structures significant.

CHAPTER 2. SITE PLANNING/LANDSCAPE DESIGN
PART 1. GENERAL

2.1.1 Purpose and Scope. This chapter provides the general objectives, considerations, and procedures of site planning and landscape design. For new construction, planning and design shall be for a predetermined site identified to the Architect-Engineer (A-E) by the Agency. It is also assumed that a detailed study of the requirements of the project, its employees, its visitors, and facilities to be included in the site plan have been determined during the programming phase.

2.1.2 Objectives:

a. **Site Potential:** Full advantage shall be taken of existing site and landscaping potential by preserving the site's natural features to the greatest extent possible.

b. **Relationship of Elements.** A proper and harmonious relationship should be established between elements on a common site, and between the site and the surrounding environment.

c. **Functionality and Efficiency.** Provide a site plan and landscape design that are economical to construct, functionally efficient, and easy to maintain.

d. **Energy Conservation.** The site plan and landscaping scheme shall contribute to the energy efficiency of the project through use of natural site features, plantings, etc.

e. **Accessibility.** Select materials, and design landscaping features to allow unrestricted use by individuals with physical disabilities.

2.1.3 Coordination: The site planning and landscape design shall be coordinated with related architectural, structural, mechanical, and electrical work.

2.1.4 Basic requirements. The site planning and landscape design shall comply with applicable codes and standards governing the work and other requirements described in Chapter 1.

PART 2. ELEMENTS OF SITE DESIGN

2.2.1 Physical Character of the Site. To achieve the objectives of good site planning, the designer must analyze the physical character of the site and the surrounding area, develop a design that both respects and reinforces the individual character, and takes into consideration the following:

a. **Topography.** The topography shall form a strong influence on design of the project site. On large project sites of open campus-like development, every effort shall be extended to blend the development with existing contours. For projects within urban areas where site area is limited, the topography within and surrounding the site is equally important.

b. **Natural Features.** Natural site features such as existing trees, ground forms, and water shall be preserved and utilized to the maximum extent possible.

c. **Undesirable Conditions that Surround the Site.**

1) Hazards and nuisances adjacent to the project site must be considered when developing the site plan. Adverse effects of such factors as excessive noise, odors, smoke, dust, etc. must be alleviated to the extent possible by proper orientation of the structures, grading, planting screens, and protective buffer strips.

2) Pursuant to Executive Order 11988, Floodplain Management, and Executive Order 11990, Wetlands Protection, ARS is required to avoid direct or indirect support of floodplain development and new construction in wetlands wherever there is a practicable alternative. When there is no practicable alternative, and if the site is located in a floodplain, wetland, or could be exposed to flood hazards, this fact shall be stated on the working drawings. If so, occupied spaces and mechanical and electrical components shall not be located below the anticipated high water level.

2.2.2 Grading and Drainage. Grading schemes shall consider the following:

a. Disposal of surface water as quickly as possible.

b. Preservation of the character of the natural terrain by minimum disturbance of existing ground forms.

c. Balancing of cut and fill.

d. Avoidance of steps in sidewalks.

e. Meet ground level of existing trees to be saved, or plan for tree wells as a part of the overall site design concept.

f. The minimum desirable slope for turf areas shall be not less than 1.5 percent. Maximum slope for turf areas shall not exceed one foot rise in 3 feet of run.

g. Minimum slope for parking and terrace areas shall be not less than 1.5 percent or more than 7 percent.

h. Proposed contours must meet existing grades at the property line or contract limit lines in smooth flowing curves.

i. Banks with slopes in excess of one foot of rise in 3 feet of run are too steep for mowing A vine or shrub type ground cover shall be installed to ensure slope stabilization and reduce maintenance. If a design results in slopes of 2 to 1 or steeper, a retaining wall or revetment shall be provided.

j. Surface drainage shall be directed to drainage structure inlets within the site limits.

2.2.3 Pedestrian and Vehicular Circulation. Pedestrian and vehicular traffic patterns shall be direct, convenient, safe, and allow for accessibility by individuals with physical disabilities.

a. Design of pedestrian walkways shall provide for direct movement between facilities rather than being based on rigid geometric patterns.

b. Pedestrian and vehicular traffic shall be separated to the extent possible.

c. Alignment of roads shall be designed for directness of approach with contours as parallel as possible to avoid undue cut and fill.

d. Perimeter roads generally separate vehicle and pedestrian traffic conflicts when pedestrians are traveling from the parking areas to the building.

e. Access for emergency vehicles shall be provided.

2.2.4 Ramps. Ramps shall be designed for adequate movement of all types of traffic.

2.2.5 Plazas, Courtyards, and Roof-top Gardens. If plazas, courtyards, and roof-top gardens are proposed, they shall be inviting and comfortable spaces, clearly responding to user needs, and must be accompanied by supporting documentation that was approved during the programming phase of the project. The facilities to be provided shall be based on what is needed to serve the building employees and visitors to the site.

2.2.6 Planters. When planters are to be used for tropical plants in a building or landscape plantings on the building, a determination shall first be made as to what plant material will be used so that planters of sufficient size will be provided to support an adequate root system. The mature size of the plant material must be known to determine the structural support system under the planter. Artificial light shall not be used solely to support plant life. Adequate water supply and drainage shall be provided.

PART 3. ELEMENTS OF LANDSCAPE DESIGN

2.3.1 Landscape Design Principles.

a. The landscape design shall be an integral component of the total project environment, and shall respect and preserve its existing natural attributes.

b. The landscape maintenance capability of buildings management, or designated service contract, shall be a major consideration in the amount and complexity of the landscape design.

c. The design shall be kept simple in farm but of sufficient quantity to create the mass effect of the design concept.

d. The use of hardy plants that will thrive in the climate hardiness zone of the site is mandatory.

e. Living plants have set habits of growth, texture, form, and color. These habits must be fully understood to avoid overplanting, excessive maintenance, and conflict with other plants and structures.

f. The screening of objectionable views and the visual separation of functional elements is desirable; however, visibility and easy accessibility shall be provided for fire department connections.

g. Use of deciduous plantings adjacent to west and south facing walls shall be encouraged for those climates with seasonal change.

h. Areas within the project boundaries, except those clearly intended to be modified by development, shall be preserved in their existing condition, or so improved that they will be compatible with both the new construction and the surrounding landscape.

2.3.2 Planting in Public Spaces. The Agricultural Research Service (ARS) has no authority to expend funds to plant trees or shrubs in areas not owned by the Federal Government. If a city has a master plan for street tree planting, the project landscape architect shall coordinate with the city plan. The project plan shall then be submitted to the city for inclusion in its next street improvement project. However, many city codes require that street tree plantings must be included in all building projects. Local codes should be followed using the type of tree specified on the street tree plan.

2.3.3 Planting Within or Above Portions of Buildings. Planting within or above portions of buildings poses special problems in the selection of plant material and the provisions to maintain the plantings.

a. Planting around air exhaust openings and over utility tunnels shall be avoided whenever possible.

b. High winds and extreme temperature changes require added maintenance far plants within, or on, buildings.

PART 4. SITE PLANNING/LANDSCAPE DESIGN PROCESSES

2.4.1 General. Site planning and landscape design, like the other design processes, demand that several tasks be performed and several plans be produced in order to develop a responsive, effective design.

2.4.2 Coordination of Design Professionals.

a. In any project that includes a substantial site area development, it is essential that a landscape architect be a member of the project design team. The landscape architect must maintain a close liaison during each design phase of the project. Decisions regarding the location and operation of the mechanical, structural, and utility systems have a major impact on the site plan and landscaping. Cooperative decisions as to how and where they can best be accommodated are mandatory. In order to become acquainted with the area and its surroundings, the designer shall make frequent visits to the site daring the stages of site plan development. This will facilitate accurate determination of the proposed plan's adaptability to the site.

b. If landscape design drawings are required, a registered landscape architect shall prepare the landscape plans.

2.4.3 Site Surveys. Before preparing project site studies, comprehensive information an existing site and landscape conditions, in the form of site surveys, shall be obtained or developed and evaluated. These surveys shall include, but not necessarily be limited to, the following:

a. A topographic survey to include:

1) The established grades of city streets bordering or crossing the site.

2) High water elevations, if any part of the site is subject to flooding from streams, tides, or surcharge from storm sewers.

3) Data on existing trees, plantings, and landscape conditions including location, identification by common name, diameter of trunk (one foot above ground), approximate spread of branches, foliage outlines for the edge of woods, ground elevation at the base of isolated trees, etc.

b. Utility survey to include location and type of utility services crossing or bordering the site. A boundary survey should be included to show what, if any, additional land may be needed for utility easements, rights-of-way, etc.

c. A survey to evaluate the site for the presence of radon in accordance with Departmental Regulation 1650-3 contact the Radiological Safety Staff for information on conducting radon site surveys.

2.4.4 Site Analysis. After the site surveys have been completed, a thorough analysis of existing site and landscaping conditions shall be developed as part of the design concept phase. This analysis shall include consideration of the following site conditions: topography, views and vistas, traffic patterns (pedestrian and vehicular), noise, permanent site features, plantings, climate, solar orientation, wind conditions, environmental and historical preservation impacts, and land ownership status, including potential impacts to existing rights-of-way, easements, etc.

CHAPTER 3. ARCHITECTURAL ELEMENTS
PART 1. GENERAL

3.1.1 Scope. This chapter provides the general objectives, considerations, and procedures for architectural elements in the design of ARS buildings.

3.1.2 Coordination. The architectural design shall be coordinated with other related structural, mechanical, and electrical work. On alteration projects, the A-E shall make such visits to the site as are necessary to ensure coordination with existing work.

3.1.3 Basic Requirements. The architectural design shall comply with applicable codes and standards governing the work and other requirements described in Chapter 1.

3.1.4 Accessibility. Public Law 90-480 requires that Federal buildings, including site work, be designed to ensure that individuals with physical disabilities will have ready access to, and use of, such buildings. The ARS requires compliance with the Uniform Federal Accessibility Standard.

PART 2. SPACE REQUIREMENTS

3.2.1 Scope. Space requirements for a project shall be in compliance with applicable Federal Property Management Regulations as contained in the Program of Requirements (POR). It is the responsibility of the designer to adhere to the space requirements as contained in the POR, and to design a project that can be constructed within the time and budget constraints.

3.2.2 Building Area Calculations. These shall be defined and computed in accordance with the American Institute of Architects (AIA) Guidelines, Publication D101.

3.2.3 Building Efficiency. The ratio of net to gross area shall be established in the project management plan or design program. Spaces shall be sized to support the intended function without wasted footage. Use AIA Guidelines Publication D101 for calculating building efficiency ratios.

PART 3. EXTERIOR ELEMENTS

3.3.1 Configuration and Orientation.

a. **General.** The configuration and orientation of any new structure shall be carefully analyzed to make optimum use of site potentialities and to reduce energy consumption.

b. **Reflection to Neighbors.** When selecting highly reflective exterior finishes, the designer shall establish whether surrounding structures will be adversely influenced by increased solar load and, if so, avoid the adverse impact by properly locating these surfaces.

c. **Shading of Neighbors.** To the extent allowed by site constraints, the design shall be such that existing neighboring structures that make use of passive or active solar design shall not be compromised by the new design.

3.3.2 Roofing.

a. **Use of Consultants.** Wherever possible, trained in-house personnel shall be employed to conduct roofing reviews and inspections. Services of a roofing consultant shall be utilized only where the roofing system is exceptionally complex, where unusual problems are anticipated, or where in-house expertise is not available.

b. **Roof Drainage.**

1) Buildings with nominally flat roofs shall have the finished roofing system sloped a minimum of 1/4-inch per foot to the roof drains. Where controlled flow is a requirement for sewer hookup, storage shall be provided for the drainage system so that the roof slope requirement is maintained.

2) The pattern of roof drains, high points, and slope to drain shall be indicated on the roof plan. Roof drains shall be located at low points.

3) Roof designs that require ponding or spraying of water on the roof shall not be used.

3.3.3 Roof-Mounted Equipment.

a. **General.** Since it is a potential source of leaks, roof-mounted equipment shall be held to a minimum. Wherever possible, roof penetrations shall be consolidated or grouped together utilizing a common roof curb flashing platform.

b. **Building Operation Considerations.** Permanent access shall be provided to roof-mounted equipment requiring maintenance. The access shall be from the building interior, preferably a permanent stairway or door leading onto the roof from a penthouse or a higher portion of the building. Where this is not feasible, a permanently installed ship's ladder to a roof hatch of the counterbalanced type shall be provided. The access shall be located in a portion of the building available to operating and maintenance personnel at all times. Walkways or duckboards shall be provided on the roof along routes to and around equipment requiring maintenance. Where the walkways are close to a vertical drop of 12 inches or more, they shall be provided with handrails to prevent falling.

c. **Cooling Towers and Other Equipment.** Supports shall not be constructed directly on the roof membrane. If such equipment must be located on the roof, a supplementary elevated roof platform shall be constructed to minimize membrane penetrations. The supplementary platform shall extend a minimum of 3 feet clear around the perimeter of the equipment, and permit access to the roof surface below. Penetrations in the roof deck shall be protected against leakage. For existing buildings, the structural capacity of the existing roof structure shall be determined before equipment is redesigned.

3.3.4 Windows and Glazing.

a. **Safety Considerations.**

1) Safety glass shall be used for glazed doors and sidelights, and other areas adjacent to, or in, the line of pedestrian traffic. Spandrel glass located above pedestrian areas shall have adhered backing.

2) Partitions and exterior fenestrations that are glazed to the floor line shall have protective barriers at push bar height.

b. **Energy Considerations.**

1) Air infiltration of exterior glazing systems, whether fixed or operable, shall be no greater than 0.20 cfm/linear foot of sash perimeter, per American Society for Testing and Materials (ASTM) E 263 at a static pressure of 6.24 psf.

2) Exterior windows shall be provided with an internally controllable shading device. The type and location of shading system(s) shall be based on the building exposure

and tenant occupancy.

3) The glazing area shall be coordinated with window/wall heat loss/gain.

3.3.5 Building Entry.

a. **Weather Protection.** Weather protection for building entry areas shall be provided by such methods as building overhangs, entry vestibules, canopies, roof projections, or recessed doorways.

b. **Snow Protection.** Designs shall attempt to minimize the accumulation of snow at building entrances through use of canopies, overhangs, and other such devices.

c. **Entry Vestibules.** Entry vestibules, providing a buffer between the outside and the building interior by use of doors, shall be provided at each entrance. Revolving doors are not suitable for reasons of safety, nor are they usable by individuals with physical disabilities.

d. **Accessibility.** Building entries shall be accessible by individuals with physical disabilities as outlined in the Uniform Federal Accessibility Standards.

e. **Safety and Health Considerations.** Exterior entry doors with full height glazed panels shall have horizontal push-pull bars.

PART 4. INTERIOR ELEMENTS

3.4.1 Floors.

a. **Acoustical Considerations.** Carpet or carpet tile is required in office space designed to accommodate open-plan or office landscaped space.

b. **Maintenance Considerations.** To facilitate removal when remodeling or renovation is necessary, carpeting shall be attached to substrate with strippable adhesives, whenever it is glued. For foam backed carpeting and carpeting with separate pad, use stretch type installation.

3.4.2 Ceilings.

a. **Ceiling Height.** The minimum clear height, i.e., vertical distance from floor to lowest obstruction above, shall be 8 feet; however, there may be other job-related factors to be considered which necessitate a higher ceiling, such as addition of access floor for computer areas.

b. **Fire Safety Considerations.** A suspended ceiling is unacceptable as a component of a fire resistive floor/ceiling assembly. If a fire rating is required with steel joist construction, a permanent fire resistive membrane must be fixed to the underside of the joists. Approved designs are illustrated in the Underwriters Laboratories Fire Resistive Directory. If desired, an additional finished ceiling may be suspended below.

c. **Maintenance Considerations.** Where it is necessary to obtain access to the space above a suspended ceiling for maintenance work, the ceiling shall be fully accessible. No panel shall exceed 15 square feet in size in order to facilitate removal by one person.

3.4.3 Doors.

a. **Dimensions.** Except for closet doors, minimum door width shall be 3 feet and minimum height shall be 6 feet 8 inches. In order to permit future lowering of suspended ceilings, tops of doors shall be a minimum of one foot below the ceiling.

b. **Hardware.** Unless otherwise required for security reasons, door latches shall not be provided for toilet doors, allowing the use of push plates, fixed knob, or handle to cause door swing.

c. **Safety and Health Considerations.** Interior and exterior doors with full height glazed panels shall have horizontal push bars. push bars shall open against a material other than glass. Revolving doors shall not be used.

d. **Fire Safety Considerations.**

1) Fire doors shall meet the requirements contained in National Fire Protection Association (NFPA) Standard No. 80.

2) Doors, hardware, and frames of fire door assemblies shall bear the label of the

Underwriters Laboratories, Inc., Factory Mutual, or other approved testing laboratory in accordance with ASTM E 152.

e. **Accessibility.** Doors and doorways shall be accessible by the individuals with physical disabilities as outlined in the Uniform Federal Accessibility Standards.

3.4.4 Finishes.

a. **Painting and Color.**

1) **General Work Spaces.** Walls within work spaces shall be painted a single neutral color. The number of coats shall be held to a minimum, but must completely cover the existing substrate, and the designer shall consider this factor in selecting the color.

2) **Lighting.** In order to reduce lighting load, light colors shall be used for painted and unpainted surfaces in general work spaces. Ceilings shall have a coefficient of reflectivity of not less than 75 percent, walls not less than 50 percent, and floors not less than 20 percent.

b. **Draperies.** Draperies shall not be included as part of the construction contract unless otherwise called for in the design program or required for architecturally specialized spaces.

PART 5. SUPPORT SPACES

3.5.1 Service Areas.

a. **Definition.** Ancillary areas of a building that house its maintenance/operational support functions.

b. **Building Operation.**

1) Building service areas shall be located to best serve their function. Partitions in such locations shall be constructed of durable easily maintained materials, such as masonry or concrete.

2) Centrally located service closets and gear roams shall be provided on each floor as close as possible to the elevators.

3) Adequate, easily accessible storage facilities shall be provided for all required exterior ground maintenance equipment.

3.5.2 Mechanical Electrical Spaces.

a. **Building Operation Considerations.** It is essential that the building design incorporate adequate access and space to permit the installation, maintenance, and replacement of mechanical and electrical equipment.

b. **Acoustical Considerations.** Effective means must be included in the design to prevent the transmission of objectionable noise and vibration. Use of acoustical material in research laboratories and animal rooms may be restricted or prohibited.

3.5.3 Parking Facilities. For dimensional criteria involving maneuvering clearances, and layouts for interior facilities, refer to the AIA publication "Architectural Graphic Standards."

PART 6. MISCELLANEOUS ARCHITECTURAL ISSUES

3.6.1 Building Accessories.

a. **Flagpoles.**

1) A ground-mounted flagpole, located at the left of the building entrance, shall be provided for new ARS buildings. Where ground-mounted poles are not feasible, a roof-mounted pole is permissible; or, if roof mounting is not suitable, an outrigger pole may be used. Only one flagpole need be provided for a complex of buildings on a common site. Flags are to be displayed on, or near, the main Administration Building at locations having two or more buildings.

2) Flagpoles shall be of standard economical design and manufacture.

b. **Public Telephones.**

1) Provisions for public telephones for building occupants and the public shall be

located in, or visible from, each public lobby.

2) For reasons of accessibility, telephone booths are not acceptable; however, recesses may be provided for telephone shelves.

c. **Identification Signs, Building Directories, and Bulletin Boards.** When required by the project, the identification signs, building directories, and bulletin boards shall be designed in compliance with the requirements specified in ARS DIRECTIVE 243.2 - Signs, Office Identification, Building Directories, and Bulletin Boards.

d. **Lightning Protection.** All metal flagpoles and metal stacks either attached to buildings or free standing shall be grounded (refer to Section 6.11.4).

3.6.2 Specifying Uncommon Products. In special laboratory or laboratory support work, it may be necessary to specify materials or products which are not commonly used and may be hard to find. In such cases it is permissible to specify the source of the uncommon product by stating the supplier's name and address, and trade name of the product subject to the following conditions:

a. When more than one source of the uncommon product is found, each source shall be named.

b. The project specification shall contain the following statement: "The use of a trade name and supplier's name and address in the specification is to indicate a possible source of the product. The same type of product from other sources shall not be excluded, provided they possess like physical characteristics, color, and texture. If the product is from a foreign supplier, it shall be subject to the Buy America Act."

CHAPTER 4. STRUCTURAL AND GEOTECHNICAL ENGINEERING
PART 1. GENERAL

4.1.1 Scope. This chapter provides general objectives and criteria pertinent to design of structural elements of buildings erected and maintained by ARS.

4.1.2 Coordination. The structural design shall be coordinated with related architectural, mechanical, and electrical work. On alteration projects, the A-E shall make such visits to the site as are necessary to ensure coordination with existing work.

4.1.3 Basic Requirements. The structural design shall comply with applicable codes and standards governing the work and other requirements described in Chapter 1.

PART 2. FOUNDATIONS

4.2.1 General.

a. **Applicability.** This paragraph establishes procedures and criteria to be used for the analysis and design of foundations for buildings.

b. **Procedures.**

1) The Architect-Engineer (A-E), with the geotechnical consultant, shall prepare documents to contract for subsurface soil exploration. The scope of work and related documents must be submitted to the Contracting Officer (CO) for approval.

2) The A-E shall submit recommendations for foundation systems based on data contained in the subsurface investigation report. An economic comparison of the alternate foundation systems shall be made and submitted with each tentative submission.

3) After review and approval of the design concept by the Engineering Project Manager (EPM), the A-E shall prepare the foundation design.

4) Consultant geotechnical engineering services shall be provided for projects and related work that require subsurface engineering analysis.

4.2.2 Subsurface Investigation.

a. The A-E, along with the geotechnical consultant, shall develop the subsurface investigation program. The subsurface investigation shall be of sufficient scope to provide the A-E with adequate information for the design of the foundation system.

b. **Soil Borings.** Where borings are required, the A-E shall prepare a boring location plan and specifications in conformity with requirements of this chapter.

c. **Contracting for Subsurface Investigation.** Upon written authorization from the C0, the A-E shall contract for the subsurface investigation work. The contract shall be awarded after authority for right of entry onto the property has been issued, and after approval by the CO of the soils investigation contract.

4.2.3 Foundation Design-Concept. The A-E shall prepare a Geotechnical Report on the subsurface investigation, including the geotechnical consultant's recommendations for type of foundation, allowable soil bearing values based on bearing capacity and settlement analysis, and protection against surface and subsurface water. The report shall be submitted to the CO for approval. The Geotechnical Report shall contain a pro-con evaluation of foundation systems and subsystems and a cost comparison of each system.

4.2.4 Foundation Design.

a. **Basis for Foundation Design.** Foundation design shall proceed on the basis of the approved Geotechnical Report. Foundations must satisfy the following requirements:

1) Ultimate bearing capacity of soils must be sufficiently larger than design loads to ensure foundation safety.

2) Total differential settlements must be sufficiently smaller than settlement tolerance of the structure to ensure that the structure will function properly.

3) Effects of the structure and its construction operation on adjoining property, buildings, and facilities must be examined and evaluated, and protective measures must be taken.

b. **General Requirements.**

1) **Foundation.**

   (a) Footing shall be located 1 foot below the frost line;

   (b) Footings shall not be located in zones of high volume change due to moisture fluctuations; and

   (c) Footings shall not bear on soft or uncompacted soils.

2) **Water-table.** The water table and its fluctuation record should be obtained before establishing elevation of the foundation.

3) **Bracing in seismic area.** Individual footings on pile caps shall be braced to resist lateral forces in seismic area in accordance with requirements of the Governing State/local building code or Federal standards.

c. **Protection and Support of Adjoining Property.**

1) **Local Requirements.** Building codes of cities differ in the requirements for the protection of adjoining property. Local building codes shall be checked in each case to determine where temporary or permanent protection is required. When construction of such protection requires access to adjoining property, the CO shall be notified so that he may, through the ARS General Services Division, obtain the necessary permit.

2) **Sheet Piling, Underpinning, Shoring, and Bracing.** The construction contractor shall design and provide sheet piling, underpinning, shoring, and bracing to protect banks and sides of excavation, buildings, structures, facilities, and utilities adjacent thereto against damage, including that from surface drainage. The project specifications shall be developed to require the construction contractor to conduct a survey of the condition of adjoining properties, including photographs and records of prior settlement or cracking of walls, partitions, or floors that may became the subject of possible damage claims. Before start of construction, a complete survey report shall be submitted to the CO or designated representative.

   The A-E and his geotechnical consultant shall review design calculations and construction drawings to ensure that the construction contractor's design and construction procedures are safe, and satisfy design criteria and geotechnical recommendations.

3) **Footings on Public Property.** Permission shall be obtained from city authorities before proceeding to project footings beyond the lot line onto public property.

4.2.5 Retaining Walls. Retaining walls must satisfy independent requirements as follows:

a. To make the structure safe against failure by overturning and excessive settlement, pressure beneath the base must not exceed the allowable soil pressure, and the structure as a whole must have an adequate factor of safety with respect to sliding along its base or along some weak stratum below its base.

b. The entire structure, as well as each of its parts, must possess adequate strength. Corresponding pressures and forces provide the basis for checking the ultimate structural strength at various critical sections.

c. **Design Requirements.**

1) Exposed faces of retaining walls shall be battered 1/2 inch per foot of height to avoid the appearance of tilting.

2) The bottom of the base of retaining walls on soil shall be below the frost line, but not less than 2 feet below the finished grade at the exposed face of the wall.

3) Four-inch diameter weep holes shall be provided far drainage, placed 6 inches above the lower grade at the exposed face of the wall, and spaced not more than 15 feet on centers.

4) Joints in retaining walls shall be provided in accordance with the requirements for reinforced concrete or masonry units laid with mortar.

PART 3. STRUCTURAL SYSTEMS

4.3.1 General. The design of structural systems shall conform to the following code and standards.

a. Civil Engineering Handbook - American Society of Civil Engineers (ASCE)

b. Sewer Design and Construction - ASCE

c. Waste Water Treatment - ASCE

d. Steel Construction Manual - American Institute of Steel Construction (AISE)

e. Timber Construction Manual - American Institute of Timber Construction (AITC)

f. Asphalt Paving Manual - Asphalt Institute (AI)

g. Asphalt Handbook - AI

h. Manual of Uniform Traffic Control Devices - American National Standards Institute (ANSI) D6.1

i. Building Code Requirements for Reinforced Concrete - American Concrete Institute (ACI)

4.3.2 Stability. Structures shall be designed with a lateral-resistant system to meet stability requirements that conform to recognized engineering principles. Design stability shall provide resistance against sliding, uplift forces, and overturning moments caused by wind, gravity, and seismic forces. Choice of resistant system shall be made by comparing rigidity of horizontal elements (floors and roof) with that of vertical elements (frame and walls).

4.3.3 Overall Considerations. The optimum structural system for a given application is one that will satisfy functional and architectural requirements of the finished structure at minimum cost. Consideration shall be given to future uses of the structure, possibility of alterations, maintenance costs, and ease of demolition of temporary structures or dismantling of portable structures. Preferred systems utilize material efficiently, provide maximum usable space, minimize use of special equipment, and can be constructed by following conventional procedures.

4.3.4 Selection Factors. A cost study of various structural systems shall be performed and submitted to the Engineering Project Manager (EPM) for approval.

4.3.5 Preliminary Considerations.

a. Use materials, sizes, or shapes readily available.

b. Select materials in consonance with the fire rating requirements of the structure.

c. Use materials and construction methods familiar to local labor.

d. **Modular Design.** Coordinate modular design features with architectural requirements favoring repetition of units. Beam depths and spacing, column spacing, floor heights, locations of openings, and clearance are typical considerations.

e. **Wall Bearing Versus Framed Structures.** Before selecting the type of framing system, determine if the structure is to be wall bearing or framed. Weigh the following factors:

Factor	Comments
Height of structure	Wall bearing construction usually is limited to low-rise structures.
Wall Openings	Framed structures are desirable where building walls are pierced by many openings.
Shock and seismic loads	Wall bearing structures are desirable for seismic loads, if intersecting cross walls are provided and if walls, floors, and roofs are rigidly connected. If the above provisions cannot be met, framed structures are preferable.
Slanting construction	Wall bearing structures, subject to above limitations, are inherently shock-resistant, suitable for slanting construction.
Structural materials	Structures utilizing masonry walls and timber framing are more readily adaptable for wall bearing construction than reinforced concrete or steel framed structures.

PART 4. EQUIPMENT SUPPORTS

4.4.1 Design Loads. The recommended design live loads shall be in accordance with governing code requirements for intended functional use.

4.4.2 Loads. Increase live loads to provide for the impact allowance for reciprocating and rotating machinery.

a. **Torque Loads.** Torque loads are produced by magnetic reactions of electric motors and generators which tend to retard rotation. Use five time normal torque in the design of the supporting members.

$$\frac{7{,}040\ (kw)}{rpm}$$

b. **Inertia Forces.** When computing load requirements and equipment supports, consider effects of inertia forces created by reciprocating notion or unbalanced rotating parts.

4.4.3 Vibration. Supports for high-speed machinery having heavy vibrational tendency, such as turbogenerators, turbine-driven or motor-driven plops and fans, and motor generators, shall be designed to reduce vibration to a minimum.

a. **Deflections.** Design beams or girders supporting machines so that maximum deflection will be within accepted limits (impact included), with the span taken as the distance, center-to-center, of columns and ends considered as supported without restraint. The structure shall be designed so that a horizontal transverse force, equal to one-half of the weight of the machine, applied at the level of the shaft, will not produce a horizontal deflection greater than 1/50 of an inch at the base of the machine.

b. **Isolation.** Consider use of vibration and shock isolators to reduce magnitude of the force transmitted to supports for the machinery. Consider use of vibration absorbers where it is required to eliminate vibration of supporting structure.

4.4.4 Foundation Considerations. Foundations for vibrating machinery require careful consideration.

a. **Foundation Weight.** Minimum weight of the foundation shall be 1.5 times the weight of vibrating machinery. In determining required foundation weight, consider proportion of the weight of rotating or reciprocating part of the machine to total machine weight and restrictions on lateral movement of the foundation.

b. **Isolation of Foundations for Vibrating Machinery.** Foundations for heavy machinery shall be completely isolated from foundations and floors of buildings. The gap between machine foundation and other construction shall be at least one inch. This gap shall be maintained clear or filled with a soft caulking material. The bottom of the machine foundation shall not be above foundations of neighboring buildings.

PART 5. ARCHITECTURAL-STRUCTURAL INTERACTION

4.5.1 Drift. Lateral deflection of a building under wind or seismic loading shall be such so as to preclude creating discomfort for occupants or damage to the superstructure. Specifically, when lateral stability is afforded by moment-resisting framing, deflections of frames must be allowed to occur by providing tangible connections between masonry walls and concrete columns, walls, or beams. This form of construction shall also be considered where tall flexible shear walls are utilized in multistory buildings to obtain lateral stability. The Architect-Engineer (A-E) shall develop supporting calculations to verify acceptable building response under lateral loading, and shall follow the process of designing a high-rise building as outlined below.

a. Establish criteria for minimum lateral stiffness, supported by an established authority.

b. Find the geometry that results in the least material to safely sustain stresses.

4.5.2 Anchoring Exterior Walls. Anchoring or bonding of exterior wall elements, such as facing stones or brick veneer, cornices, copings, precast panels, and ornamental features, shall be designed to ensure adequate support for such elements. Anchoring or bonding system shall be jointly developed by the architect and the structural engineer. Provision shall be made for the following:

a. **Capacity.** The system shall take into account weight of the element itself plus loading due to wind, earthquake, or blast for which the structure was designed, construction tolerances, and loadings induced by erection process.

b. **Movement.** The system shall be designed to permit anticipated movement of the element due to thermal expansion, moisture expansion, and deflection or creep of supports.

4.5.3 Nonstructural Partitions. These shall be designed and constructed to remain stable and to function compatibly with the building. Walls and partitions for interior space compartmentalization shall not be used inadvertently as structural components because of insufficient allowances for assumed or actual deformation of building structure.

4.5.4 Curtain Walls. Curtain walls and exterior nonstructural enclosures shall be designed and constructed with suitable support and anchoring systems to function compatibly with the rest of the building.

4.5.5 Floor and Ceiling Details. Attention shall be given to type of floor covering and finishes, and to type and location of ceilings to establish correct measurements and location of structural system. Sufficient information shall be provided in contract documents by the structural engineer to convey construction requirements.

4.5.6 Cladding and Insulation. Type, location, and thickness of cladding and insulation to be used separately or together shall be coordinated with design and construction requirements. Adequate support and anchoring shall be designed for cladding and insulation.

4.5.7 Stairwells. Design and construction of stairwells shall be consistent with maintaining structural integrity and stability of stairwells and building frames. Requirements for enclosing stairwells shall be addressed in design phases.

4.5.8 Glass and Glazing Details. The structural engineer shall provide satisfactory design systems incorporating glass and glazing details to be used in the building. Their adequacy to withstand actual and assumed forces shall be considered by the structural engineer. Coordinate structural requirements with the architect.

4.5.9 Waterproofing. Attention shall be given to requirements for the type, location, and extent of waterproofing which shall be consistent with the requirements of the building structure.

PART 6. REPAIR AND ALTERATION

4.6.1 Applicability. Provisions of this part cover extension, renovation, repair, and alteration of existing buildings and structures.

4.6.2 Design Requirements. The A-E shall be responsible for gathering information necessary to execute the professional services contract. The project may require the following functions to be performed.

a. **Existing Drawings.** Construction or as-built drawings shall be reviewed and data shown thereon shall be verified by field observations and measurements, before the information is used to develop a new design.

b. **Subsoil Investigation.** The A-E shall appraise existing subsoil information; shall determine the extent of additional subsurface investigation required; and shall submit proposed foundation design concept based on review of new or existing subsurface information.

c. **Exploratory field work.**

1) In the absence of original contract documents, or when information is required to define in-place construction, the structural engineer shall determine the nature, location, and extent of exploratory field work.

2) Chemical analysis may be used as a means of establishing procedures for welding to older steel framing.

3) The Magneto-inductive method (reinforcing bar detector) may be used to determine size and location of reinforcing in the concrete members.

d. **Structural Calculations.** A decision to use existing structure for purposes not originally intended shall be supported by structural calculations for affected framing elements. Calculations may reflect current design approaches such as live load reduction factors and unit loads for various occupancies. Careful judgment, supported by necessary testing, shall be exercised as to whether the usefulness of deteriorating members can be effectively extended.

4.6.3 Fire Safety. For extensions to buildings, the fire-resistant rating of existing structure shall be upgraded to conform to current fire safety criteria. If this is not feasible, fire wall separation may be required to isolate new from existing areas. In no case shall a major alteration reduce the fire-resistant rating of the building below that afforded by the original structure.

4.6.4 Foundations. The ability of new foundations to support new construction adjacent to old construction must be carefully considered. Where stress applied to the soil may cause consolidation of the soil, the architect-engineer shall establish initial floor elevations to accommodate anticipated vertical movement so that final adjacent surfaces in connecting halls and passageways are at or near the same elevation. The effect of construction operations on existing structure, such as pile driving, shall be recognized and guarded against. An estimate of settlement anticipated, supported by calculations, shall be included with the submittal by the A-E. Use of reduced allowable bearing pressures for spread foundations, or use of foundations such as caissons or piles, for new construction may reduce differential settlement between old and new structures. Preloading of the site may also be considered, provided it does not adversely affect the old construction. To allow for possible differential settlement between new and old construction, use of expansion joints may also be investigated.

4.6.5 Connection to Existing Framing. Contract documents shall clearly delineate aspects of construction that require special attention. Following is a partial list of items that shall be covered:

a. Existing steel framing shall be adequately shored and braced if extensive welding is to be made thereto.

b. When holes or expansion shields are to be installed in existing concrete framing elements, extreme care shall be exercised to avoid cutting or damaging main reinforcement. The Magneto-inductive method (reinforcing bar detector) may be a useful tool to determine the location of the reinforcement.

c. If a special sequence is essential for the successful completion of construction, it shall be clearly defined in the drawings and specifications.

4.6.6 Contract Documents. These shall be developed in a manner that will clearly indicate the work to be performed. In addition, a system shall be devised that will clearly differentiate between new and existing construction; and will define the limits of the contract.

4.6.7 Wind and Seismic Designs. Often, construction details of older buildings are not consistent with current criteria for wind or seismic loading. Therefore, careful judgment (supported by structural calculations) shall be used to determine whether the new and existing unit should be separated, or tied together to make them respond in unison. The latter approach is reserved for low, light structures where connections can be devised that will satisfactorily transmit internal stresses. The tendency of adjoining structures to sway out of phase shall be considered in establishing the width of separation or the adequacy of the structural connection between them. In establishing requirements for an earthquake joint, the A-E shall consider whether it is satisfactory to make the joint width twice that of the static drift of the structure.

CHAPTER 5. MECHANICAL
PART 1. GENERAL

5.1.1 Scope. This chapter provides general objectives and criteria for designing mechanical systems.

5.1.2 Coordination. The mechanical design shall be coordinated with project related architectural, structural, and electrical work. On alteration projects, the A-E shall make such visits to the site as are necessary to ensure coordination with existing work.

5.1.3 Basic Requirements. The mechanical design (i.e., HVAC, plumbing, and fire protection) shall comply with applicable codes and standards governing the work and other requirements described in Chapter 1.

5.1.4 Economic Design. Mechanical systems shall be designed to permit acceptable competitive bids. Equipment and systems shall be efficient, functional, and economical in construction, operation, and maintenance.

a. The A-E shall consider the requirements for HVAC on an integrated basis when performing an economic analysis comparing viable energy efficient systems. A minimum of two alternative systems in addition to the base system shall be considered.

b. It is the policy of ARS that the use of variable air volume (VAV) systems be confined to administrative and support areas of buildings where air balance and room pressure relationships are not critical factors. However, VAV systems may be used in laboratory spaces with SHPS concurrence.

5.1.5 Accessibility.

a. **Access to Machines and Equipment.** Clearance shall be provided around machines and equipment for removal of parts for repair or replacement. An average size person should have ready access to any component requiring servicing. Door or window openings, removable panels in building walls and corridors shall be arranged so that large machine or equipment parts or sections can be removed and replaced without structural changes or movement of other equipment. The A-E shall arrange to provide openings and passageways of sufficient size to permit use of standard equipment. Where this is not possible, dimensions of the limiting openings shall be clearly shown on drawings, or specified. Particular attention shall be given to equipment such as boilers, large tanks, refrigerating machines, condensers, switchgear, and transformers.

b. **Parts Handling.** Suitable means shall be provided for lifting and moving cooler and condenser heads, fan sheaves, pump casings, strainer covers, motors, gear boxes, compressor casings, and similar parts weighing over 50 pounds. Type of lifting equipment used in each case must be determined on the basis of the number of machines in a group, size and weight of parts, accessibility, and probably frequency of use.

c. **Overhead Equipment.**

1) Catwalks, ladders, chain wheels, etc. shall be provided, as required, in high machine rooms. Overhead piping and equipment in high rooms shall, where possible, be arranged to permit grouping the maximum number of valves and other operating devices within reach of a short platform, catwalk, ladder, etc., or to permit orderly grouping of valve chains where they will not be hazardous obstructions.

2) Doors of panels shall be provided for access to valves or other equipment (requiring periodic examination) above suspended ceilings. If, for architectural or other valid reasons, such access cannot be used, provide either:

(a) Catwalks above the suspended ceilings; or

(b) Concealed ladders located in closets or other suitable spaces.

3) Water lines to equipment shall not be installed over electrical panels.

5.1.6 Environmental Controls.

a. Mechanical systems, including those powered by fuel at the site, shall be designed to meet applicable Federal, State, and local requirements for abatement and control of air and water pollution, and noise control.

b. In the event of a difference between Federal, State, or local requirements, the most stringent shall apply.

PART 2. PLUMBING

5.2.1 Scope. This part deals with plumbing requirements for new buildings, repair and alteration projects, and incorporated in such buildings.

5.2.2 General Requirements.

a. Work shall be designed to comply with the following requirements as a minimum:

1) National Plumbing Code (NPC)

2) American Gas Association (AGA), National Fuel Gas Code

3) American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), Service Water Heating

4) Food Service Sanitation Manual FDA 28-2081 (1976)

b. Deviations from the above to comply with requirements, regulations, and codes of local authorities shall be considered in designing the system.

c. Completely independent sanitary and storm systems shall be provided.

d. Thermal insulation for plumbing shall be provided as appropriate.

5.2.3 Fixture Requirements.

a. Fixtures shall be water conserving type.

b. For alteration projects in the same toilet rooms or areas, fixtures should match existing fixtures if possible.

c. **Criteria for Determining Number of Plumbing Fixtures.**

1) **Based on Number of Persons.** To determine toilet facilities, number of persons in the area served by each toilet room shall be used if known; otherwise, estimates shall be based on one person for each 150 square feet of new office space in the

proportion of 50 percent men to 50 percent women.

2) **Number Required.** Unless otherwise required by contract or programming data, number of fixtures in each toilet room shall conform to the figure below.

Number of Men or Women Per Toilet Room	Men Water Closets	Urinals	Lava-tories	Women Water Closets	Lava-tories
1-8	1	1	1	2	1
9-24	2	1	1	2	2
25-36	2	1	2	3	2
37-56	3	2	2	4	3
57-75	4	2	2	5	4
76-96	4	2	3	6	4
97-119	5	2	3	7	5
120-134	6	3	4	8	5

3) Since number of toilet rooms is based on convenience, it is obvious that the total number of fixtures per occupant will vary widely with building configuration. After initial selection, number of fixtures per room should be adjusted downward for economy.

4) **Handicapped Facilities.** One of each type of plumbing fixture suitable for use by individuals with physical disabilities shall be provided in each public toilet room (men - one lavatory, one water closet, and one urinal; women - one lavatory and one water closet).

5.2.4 Water Coolers and Drinking Fountains

a. **General.** Chilled drinking water when required shall be provided in buildings at 55^{o} F during occupied hours with centralized controls to turn the system (or each unit) off during unoccupied hours. Drinking water station shall be provided to or near toilet rooms and shall not be provided in entrance lobbies, or where hazardous materials are stored. A separate isolated line shall be installed when drinking water is provided in laboratory areas.

Drinking water station shall be suitable for use by individuals with physical disabilities. Special requirements shall be as outlined in uniform Federal Accessibility Standards.

b. **Type of System.** Water shall be chilled by standard packaged self-contained drinking water units (electric water coolers). A central water chilling plant to supply chilled drinking water to fountains at various locations may be considered if cost effective.

5.2.5 Floor Drains.

a. **General.** Floor drains shall be installed in boiler rooms, mechanical equipment rooms, kitchen and dishwashing areas, garages, and similar areas. Floor drains shall not be installed in certain areas where possibility of spills of harmful chemicals and like materials exist.

b. **Traps for Floor Drains.** Floor drains shall be provided with individual traps. Provision for automatic primers shall be made to ensure that traps for floor drains connected to sanitary sewers are sealed. Special trap depths are required for containment laboratories and animal rooms.

5.2.6 Sanitary System.

a. **Fixture Elevations.**

1) Each plumbing fixture and floor drain shall be installed so that the invert to the trap is not less than 3 feet above the top of the sewer into which it discharges.

2) Where plumbing fixtures cannot be installed as required in 1) above, automatic sewage ejector system shall be provided.

b. **Cleanouts.** Refer to NPC. Where a cleanout will interfere with architectural finish of a room, a finished brass cover shall be installed over the cleanout.

c. **Sewage Ejectors.**

1) **General.** These shall not be used if other methods can be employed to allow gravity flow. If feasible, locate toilet facilities on an upper floor to avoid the use of a sewage ejector. Where ejectors are required, only lower floor facilities shall drain to ejectors. Upper floor

facilities shall drain by gravity to the main sewer.

2) **Types of Ejectors.** Duplex sewage pumps shall be installed. Pumps shall be non-clog, screenless ejector type, with each discharge not less than 4 inches. The type that allows liquids only to flow into the basin, with solids retained in a strainer located in the pump discharge line, or the pneumatic type, should be used where required.

d. **Special Wastes.**

1) **Acid Wastes.** Separate drainage and vent systems for acid wastes shall be of the corrosion-resistant material.

2) **Neutralizing Device for Corrosive Wastes.** Corrosive liquids, spent acids, or other harmful chemicals that might destroy or injure a drain or vent pipe, or create noxious or toxic fumes, or interfere with sewage treatment processes, shall be thoroughly diluted, neutralized, or treated. A properly constructed and acceptable dilution or neutralizing device shall be provided. Depending on type of treatment required, this device shall be provided with either, or both, an automatic supply of diluting water, or a neutralizing medium, so as to make its contents noninjurious before discharge to the drainage system. Discharge of corrosive and method of treatment shall be coordinated with and approved by local code authorities. Special isolation and sealing are required for contained mechanical equipment and devices in laboratories, animal rooms, greenhouses, etc.

5.2.7 Storm Water Drains.

a. Roof drains shall be located in areas where deflection of the roofing system occurs, rather than above or near columns. Locations shall be coordinated with architectural requirements.

b. Provide cleanouts in storm water lines, as required, for sanitary drain lines.

5.2.8 Water Supply System.

a. **Water Treatment.**

1) **Chemical Analysis.** A chemical analysis of the water supply must always be obtained.

2) **Softeners.** Treatment of cold water is usually not necessary where water is obtained from a municipality or from a corporation. Water softeners shall be installed, if required, for treatment of water supplied to water heaters or boilers. For large boiler plants, an extensive study and treatment system will be required. Water softeners shall be installed in strict accordance with instructions from the manufacturer and applicable codes.

b. **Water Piping Materials.** Local engineers and water company officials should be consulted regarding the performance of different kinds of pipe in a particular locality. Where pipes of incompatible materials are joined, dielectric couplings shall be provided.

c. **Water Pressures Required.**

1) **Fixtures.** Minimum water pressure required on the top floor of a building is 15 psi at the most remote plumbing fixture, except blow-out type water closets and urinals, which require 25 psi.

2) **Fire Sprinkler and Standpipe Systems.** Refer to the latest NFPA Codes and standards for requirements.

3) **Types of Systems to be Used.** When street pressures are not adequate to maintain pressures indicated above, provide a booster pump, a pneumatic system, a constant pressure, or a maintained pressure pumping system.

d. **Service Pipe.** In large buildings, two sources of water supply from different mains are desirable. Service lines must enter the building in an accessible location. They must never enter fuel rooms, storage rooms, switchgear rooms, or transformer vaults. A swing type joint shall be provided for a service line at its entrance to the building.

e. **Interior Water Piping.**

1) **Backflow Protection of Water Piping Systems.** Water distribution systems shall be protected against backflow (the flow of water or other liquids into distributing pipes from a source or sources other than the intended source). Refer to latest NPC edition for requirements.

2) **Pressure-reducing Valves.** Valve shall be installed on the domestic water mains or branches where a pressure in excess of 70 psi may be expected. A valved bypass, one

pipe size smaller than the main size, shall be provided around pressure-reducing valves. The valve in the bypass shall be of the globe pattern. Specifications shall state the initial pressure, required flow, and final pressure.

f. **Valves.**

1) **Location.** Locations and types of valves must be shown on drawings and must be accessible, identified with suitable markers.

2) **On Mains.** Valves shall be installed on cold water, hot water, and hot water return circulating mains so that sections of mains may be shut off without disturbing the services to other parts of the building. In addition, a valve shall be provided on the main supply at its entrance to the building and on the inlets and outlets of mechanical equipment requiring water connections.

3) **On Branch Connections.** A shut off valve located close to the main shall be installed on each branch connection off the main serving more than one fixture. Valves shall be provided at the base of risers.

4) **Additional Valves.** A valve shall be installed on the supply to each toilet room where the riser supplies more than one toilet room, and on the connection to each wall hydrant and lawn faucet. Drain valves with hose ends shall be provided at the low points of systems and at the base of risers.

g. **Sizing of Piping.** Refer to the latest NPC edition.

h. **Domestic Hot Water.**

1) **General.** Equipment shall be automatically controlled and shall have sufficient capacity to deliver a minimum of 105^{o} F water. Provide centralized controls to turn equipment off during unoccupied hours.

2) **Type of Heater.** Fuel or energy selected for water heating shall be determined by availability and cost. Type selected may be steam, gas, oil, electricity, solar, or central station steam.

3) **Sizing of Heaters.** Should be in agreement with the latest ASHRAE Handbook.

4) **Requirements for Kitchen-Cafeterias and Special Areas:** A separate domestic water heating system shall be provided to supply high temperature water requirements of cafeteria equipment. Controls shall be provided to turn off equipment during unoccupied hours. Chemical sanitation methods approved by FDA may also be used which reduce water temperature requirements to 140º F. Similar systems shall be used for special areas, such as photo labs.

5) **Circulating Piping (Hot Water).**

a) **Hot Water Supply Piping.** Return circulating pipes shall be installed where the length of hot water supply piping exceeds 100 feet.

b) **Hot Water Equipment.** The main circulating line of hot water equipment shall be provided with gate valves, check valves, aquastat, and circulating pump. Provide automatic controls to turn off circulating pump when building is unoccupied.

I. **Fire Protection Systems.**

1) **Coordination.** Plumbing systems shall be coordinated with requirements of fire protection systems, which may include automatic sprinkler systems, fire pumps, fire standpipes, fire hydrants, mains, water tanks, or fire department connections.

2) **Potability.** Extreme care shall be taken to ensure that potable water for the domestic system is maintained. Design shall require safety precautions, such as backflow preventers and other safety devices, to protect the domestic water system when cross-connections are made with other systems.

5.2.9 Gas Piping.

a. **Design.**

1) **Standards.** Gas piping shall be designed using the latest edition of NFPA Standard No. 54 and ANSO Z 223.1, National Fuel Gas Code.

2) **Objectionable Locations.** Gas piping shall not be run in trenches, tunnels, furred ceilings, or other confined spaces where leaking gas might collect and cause an explosion. Underground piping in buildings and above ground in areas subject to fires, such as trash

rooms, shall be avoided.

3) **Point of Entry.** Gas piping entering the building shall be protected against the possibility of breakage due to vehicular traffic, settling, or vibration. Where safe and practical, the pipe should be brought in above grade and provided with a swing joint before entering the building.

b. **Ventilation.**

1) Gas meter rooms and places containing major gas-supplied equipment, such as gas-fired boilers, gas-engine emergency generators, or other equipment using large quantities of gas, shall be ventilated to ensure removal or leaking gas.

2) When major gas-supplied equipment such as gas-fired boilers or a gas engine emergency generator, using large quantities of gas, is located on upper floors or on the roof of a building, gas supply piping shall be located outside the building or in a separate two-hour, fire-resistant shaft vented at the top and bottom to the outside so as to prevent leaked gas from accumulating in the shaft, or penetrate other portions of the building.

PART 3. FIRE SAFETY

5.3.1 Scope. This part deals with building fire safety criteria related to mechanical systems.

5.3.2 General Requirements. The requirements of the latest edition of national fire codes published by the National Fire Prevention Association (NFPA) shall be used as criteria.

5.3.3 Fire Extinguishing/Suppressing Systems.

a. **Fire Department Connection.** At least one fire department connection shall be provided for buildings that have sprinkler systems, standpipe systems, or vertical fire main systems. Standpipes and sprinkler systems shall be interconnected when possible so that each fire department connection will serve all fire protection needs simultaneously.

b. **Automatic Sprinkler Protection.** Automatic sprinkler protection shall follow the requirements of the National Fire Codes published by the NFPA. The sprinkler- standpipe system shall be designed as a separate system.

c. **Interior Fire Main System.** A vertical fire main system shall be provided in buildings at least three stories above grade. If the building is sprinklered, the system shall supply both automatic sprinklers and manual fire fighting hose outlets.

PART 4. HEATING, VENTILATION, AND AIR-CONDITIONING (HVAC)

5.4.1 Scope. This part deals with heating, ventilation, and air-conditioning systems, energy conservation, and design procedures. Coordination with other criteria is required.

5.4.2 General Requirements.

a. Work generally shall be designed to comply with the following latest codes and standards, which shall be considered the minimum for design of mechanical systems:

1) American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. (ASHRAE) Guides, Databooks, and Standards.
2) American Society of Mechanical Engineers (ASME).
3) National Fire Protection Association (NFPA).
4) American Gas Association (AGA).
5) Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA).
6) American National Standards Institute (ANSI).
7) American Society for Testing and Materials (ASTM).
8) Air Moving and Conditioning Association, Inc. (AMCA).
9) American Conference of Governmental Industrial Hygienists.
10) ARS Laboratory Chemical Fume Hoods Standards - Manual 232.1.
11) Instrument Society of America (ISA).
12) National Bureau of Standards (NBS).
13) National Electrical Code (NEC).
14) National Electrical Manufacturers Association (NEMA).
15) Scientific Apparatus Makers Association (SAMA).
16) Uniform Building Code (UBC).

b. Deviations from the above codes to comply with Agricultural Research Service (ARS) requirements, regulations, and codes of local authorities shall be applied in the design of mechanical systems.

c. Heating, ventilation, and air-conditioning systems shall be designed so that fire safety systems, such as smoke control systems, sprinkler systems, etc. are separate from each other. HVAC duct and piping systems shall also be separated from fire safety systems.

5.4.3 Design Criteria.

a. **General.** Comfort conditions to be maintained in a building are dry-bulb temperature and relative humidity, 3 to 5 feet above the floor. Designed indoor temperature will vary with the activity and intended use of the building. The A-E shall utilize his professional knowledge and expertise to identify those instances where ASHRAE Design Standards may not be appropriate for the researcher's needs. This sensitivity to researcher's needs is critical to the success of this design.

b. **Outdoor Design Conditions.** Base outdoor design conditions for heating and cooling on the ASHRAE Handbook of Fundamentals. For normal temperature/ humidity control, the 99 percent column for heating and the 1 percent column dry-bulb temperature, with its corresponding mean coincident wet-bulb temperature for cooling, shall be used.

c. **Indoor Design Conditions.** Unless otherwise specified in the project Program of Requirements, the following conditions shall be used to calculate loads and size of equipment:

1) General office space and laboratories

Cooling 76º F DB and 50% RH
Heating 70º F DB

2) Computer Rooms Year-Round, 72ºF and 40% RH.

5.4.4 HVAC Design Coordination. HVAC design shall be coordinated with other facets of construction. The following factors require special consideration.

a. **Architectural Elements.**

1) **Mechanical Equipment Rooms.** Rooms shall provide adequate space for equipment installation and maintenance. If expansion is planned, the size shall be based on future requirements. Equipment removal access shall be provided where required. Proper location of these spaces is necessary for economical air and water distribution.

2) **Shafts.** Size and location of shafts for ductwork and pipes shall be checked before ductwork and piping system design. Effects of shaft location on mechanical equipment and distribution systems shall be carefully determined.

3) **Louvers.** Location and size of outdoor air intake, relief air discharge, and exhaust air discharge louvers shall be coordinated with the architectural design. Outdoor air intakes shall be located so as to avoid intake of dust, smoke, and exhaust air.

4) **Cooling Tower Location.** Tower shall be located so as to be least obvious and, if possible, at ground level. Discharge at low levels, or where it may come in contact with buildings, shall be avoided.

5) **Access.** Location and size of control panels, and the type of service and maintenance a facility requires, shall be coordinated with the architectural design to allow personnel access to an area or to a piece of equipment.

6) **Window/Wall.** The design of window/wall shall be evaluated by the mechanical engineer to achieve comfort levels and energy conservation requirements.

b. **Structural Elements.**

1) **Foundations.** a) Dead weight of equipment in operating conditions, b) dynamic weight of reciprocating or vibrating equipment, c) size and type of equipment bases, and d) load distribution on the equipment bases.

2) **Wind Forces.** Design of outdoor equipment, such as cooling towers, stacks, and their supports, shall be based on the maximum wind velocities prevalent at the site. Exterior mechanical equipment shall be anchored, braced or guyed to withstand the prevailing wind velocity.

3) **Seismic Considerations.** If site is subject to earthquakes, design of equipment (especially outdoor cooling towers and water tanks), piping systems, ductwork, and foundations shall include suitable allowance for horizontal forces.

4) **Location.**

a) Equipment shall be located to transfer the weight directly to main structural members, girders, or columns; preferably columns.

b) Weight of equipment to be used shall be determined in relation to platforms, stairs, and elevators.

5) **Pipe Supports.** The following shall be determined before designing a system: a) weight of risers, including water column and unsupported pipe; b) lateral thrust due to expansion joints; c) dynamic forces at bends; and d) location and types of supports.

6) **Opening Through Structural Members.** Size and location of openings through structural members shall be based on the following factors: a) outside diameter of pipes or ducts, inclusive of any flange and insulation; b) standard length of pipe or duct between joints; and c) direction and extent of pitch for pipes.

5.4.5 Design Calculations.

a. 1) **Information Required for Calculations.** Calculations require information on building location, building envelope details, heat producing devices to be used in the building, and on building operation. Tables 5-1 through 5-4 list the information required.

2) **Infiltration Consideration.**

a) **Exterior Doors and Windows.** Infiltration through doors, windows, and cracks around windows and doors shall be accounted for in design calculations. For design considerations the ASHRAE fundamentals handbook shall be consulted.

b) **Exterior Walls.** Infiltration through exterior walls shall be accounted for in design calculations. For design considerations, the ASHRAE fundamentals handbook shall be consulted.

c) **Areas Under Negative Pressure.** For rooms maintained under negative pressure, infiltration shall equal the difference between amount of air exhausted and amount of air supplied.

b. Heat losses shall be calculated in BTU per hour. Heat transfer coefficients shall be taken from the ASHRAE Handbook of Fundamentals. Infiltration shall be calculated by the ASHRAE crack method. Unless otherwise specified in the project POR, heating load calculations shall be based on inside design condition of 70º dry-bulb. The heating plant shall be sized based on the calculated block heating load (space and process) plus an allowance of 20 percent extra capacity.

c. Heat gains shall be calculated in BTU per hour. Heat transfer coefficients shall be taken from the ASHRAE Handbook of Fundamentals. Unless otherwise specified in the project POR, cooling load calculations shall be based on inside design conditions of 76º F dry-bulb and 50 percent RH. The refrigerating plant shall be sized based on the calculated block cooling load plus an allowance of 20 percent extra capacity.

d. Calculate maximum load, sensible heat factor (SHF), and supply air required for each room or bay, based on the following:

1) Solar gain.

2) Lighting heat gain on wattage installed.

3) Heat gain from heat generating equipment (motors, computers, etc.) released to space.

4) One person per 125 square feet net area (office space only), if occupancy of space is unknown.

5) Include heat gain from fans and ducts between cooling coils and rooms served, unless considered elsewhere.

6) Latent heat loads must include occupants, food and miscellaneous moisture-releasing equipment, such as steam tables, coffee urns, etc.

7) 10 percent safety factor.

8) Total air quantity assigned to each room, bay, or zone depends on its sensible heat load or hood exhaust requirements (whichever is greater). Terminal temperature differential selected shall not exceed 20º F consistent with psychrometric requirements, ceiling height, and method of air distribution.

e. Calculations shall be recorded in a standard format to permit checking and to provide a reference for system modification. Design calculations shall include, but not be limited to, indoor and outdoor temperature, heat loss, heat gain, supply and exhaust ventilation requirements, humidification or dehumidification requirements, and heat recovered.

1) Heating system capacity shall be based on normal demand rather than load connected total. Where a heating plant is utilized for loads that are not simultaneous (building heating, kitchen equipment, domestic hot water and process), the system shall be analyzed for connected, normal demand, and off-peak condition.

2) Individual terminal heating equipment shall be capable of supplying maximum load for the period required without adverse effects.

TABLE 5-1
LOCATION CONSIDERATIONS REQUIRED FOR DESIGN CALCULATIONS

Considerations	**Factors**	**Information Required**
Geographical.............	Geographical location	Latitude, longitude, and attitude
	Facility orientation	Declination of the north/south axis of the facility from true north.
	Climatic conditions	Temperatures: dry-bulb, wet bulb, mean coincident wet bulb, and mean daily range. Prevailing wind direction and mean wind speed
Environmental............	Reflecting surface	Size, nature, and location of reflective surfaces at or near the site.

	Atmosphere	Scaling or corrosion properties of atmospheric contaminants.
Locality..................	Local labor and material accessibility	Availability and cost of civilian labor and materials. The available transport and access facilities.
	Standard, regulations, and codes	The applicable standards regulations, and codes.

TABLE 5-2
BUILDING DETAIL CONSIDERATIONS REQUIRED FOR DESIGN CALCULATIONS

Considerations	Factors	Information Required
Life span.................	Operation and maintenance analysis	Type of construction and economic life.
Architecture.............	Project drawings	Plans, elevations, actions and details.
Structural................	Structural elements	Physical location and size of structural elements.
	Seismic considerations building expansion, and settlement	Location, expected movement, and settlement of joints.
Construction Details......	Exterior walls and roof	Construction details, color, and insulation.

Partition walls	Thickness and type of construction.
Firewalls	Location and type of construction.
Hung Ceilings	Type of material (tile or plaster), insulating value, and size of tile or panels.
Floors	Thickness and type of construction.
Windows	Type, size, sash material, type of glass, and fixed or openable.
Doors	Type, size, and use.
Shading Devices	Internal: Type of device color, and reflectivity. External: Location and details of devices.
Stairway and elevators	Construction details, size, and usage.

TABLE 5-3
INFORMATION ON HEAT PRODUCING DEVICES REQUIRED FOR DESIGN CALCULATIONS

Considerations	Factors	Information Required
Lighting..................	Type	Incandescent, fluorescent, or high-intensity discharge.
	Mounting	Exposed, recessed in hung ceiling, recessed in return plenum, spotlights, or other mounting.
	Load	Watts per unit area including starters for fluorescent lighting.
Equipment.................	Sensible heat sources	Quantity of equipment, heat output, and usage factor.
	Sensible and latent heat sources	Quantity of equipment, amount of sensible and latent heat loads, and usage factor.

TABLE 5-4
INFORMATION ON BUILDING OPERATION REQUIRED FOR DESIGN CALCULATIONS

Factors	Information Required

Operation schedule........	Normal hours of operation and anticipated off-hours operation.
Occupancy.................	Population, usage schedule, period of maximum occupancy load, and type of activity.
Space Requirement.........	Temperature and relative humidity.

5.4.6 **Heating Systems.** Heating systems maintain the required design conditions in a space by supplying heat adequate to offset heat loss. Sources may be steam, hot water, natural gas, oil, coal, electricity, or solar energy. Systems may be combined with ventilating and air-conditioning when functionally and economically feasible. Humidification systems shall maintain required design conditions.

a. **Steam heating systems** are two-pipe systems, upfeed or downfeed, classified by steam pressure as follows:

Classification	**Operating Pressure**
Low Pressure	0- 15 psig
Medium Pressure	16- 50 psig
High Pressure	51- 125 psig

Acceptable methods for condensate return to the boiler within steam heating systems are: Hartford Return Method; Flooded Return Main Method; Dry and Wet Return Method.

Steam-heating systems are suitable for process loads and heating loads, if temperature modulation is not a prime consideration. Condensate return system shall be used with steam heating systems.

1) **Low-pressure steam systems** are suitable to heat most buildings. They are compatible with unit heaters, central air-handling units and steam-to-hot-water exchangers.

2) **Medium pressure steam systems** are suitable for process work buildings. They are compatible with central air-handling systems, when process load is large, and with steam-to-hot-water exchangers.

3) **High-pressure steam systems** are suitable for process work buildings and site distribution systems. They shall not be used directly for heating, but may be used in conjunction with steam-to-hot-water heat exchangers.

b. **New Construction.** Use of steam systems for perimeter heating is discouraged due to excessive initial costs and poor control. Steam systems may be used to provide heat to air-handling and distribution systems where economically, functionally feasible.

c. **Hot-Water Heating Systems.** Hot-water heating systems are classified by water temperature.

Classification	**Temperature F**
Low Temperature	Less than 220º
Medium Temperature	220º to 350º
High Temperature	Greater than 350º

1) **Low Temperature.** Classification is further subdivided into series loop, one-pipe, and two-pipe systems.

a) Series-loop system is suitable for use in small structures such as residences or small office buildings. Terminal units are mounted on the loop and considered as part of the loop. Flow-control devices are required at each branch.

b) One-pipe system is suitable for use with single-zone systems, as the secondary comment of a primary-secondary system. This system requires diverting tees for waterflow from the main to the terminal unit.

c) Two-pipe system is suitable to connect to individual heat emission equipment and may be either direct-return or reverse-return. It may be used for supply and return mains, or in connecting series-loop and one-pipe systems from individually conditioned spaces.

2) **Medium-temperature systems** are suitable for use in primary-secondary pumped systems with a convector/heat exchanger.

3) **High Temperature Systems.**

a) Suitable for use in central heating systems where heat is supplied from a central plant and where water-to-water heat exchangers are used.

b) Shall not be used for heating single buildings, or as direct heating system; except, where medium-pressure steam might normally be used.

c) Boilers for hot-water systems may be cast iron or steel. Where cast iron boilers are used, special consideration shall be given to air separation. Care must be exercised to prevent system pressures from exceeding boiler pressure ratings. Where low return-water temperatures are probable primary-secondary pumping, or individual circulating pumps should be provided to minimize thermal stock.

d. **Hot-air heating systems** supply air to a space at a higher temperature than the indoor design temperature. Air is normally heated by steam coils, hot water coils, electric resistance coils, or warm air furnaces. See ASHRAE handbook for criteria. In residential and small structures single-zone, perimeter hot-air systems with ductwork below the floor, or above the ceiling may be used. For larger structures, multiple single-zone units, variable-air-volume integrated with perimeter cooling, or combined hot-air systems with hot-water heating units may be used.

e. **Radiant heating systems** employ large surfaces such as floors, ceilings, walls, or a combination of surfaces, heated to temperatures slightly higher than the inside temperature. Heating medium for radiant heating systems may be water, air, or electricity. Radiant heating systems are suitable for heating concrete floors on grade, such as living quarters or vehicle repair shops. They are not suitable for industrial buildings with concrete floor on grade, or for buildings with intermittent occupancy.

f. **Infrared heating systems** are primarily used as spot heaters. Main heating units may be electric, gas-fired, or oil-fired.

1) Infrared heating systems are suitable where heating of the entire ambient air is not required, i.e., loading docks, shops, warehouses, etc.

2) For efficient use of an infrared system, line of sight and distance between the occupant and the heater shall be considered.

3) Design and installation of the system shall follow NFPA Standard No. 31.

g. **Electric heating systems** employ electricity to heat air or water. Before designing an electric system, an economic analysis that includes the demand charge shall be conducted to determine that most economical method for heating.

1) Electrical heating systems may be used in small, remote structures which cannot be heated economically by a central system or a self-contained system.

2) Where economically feasible, heating energy shall be generated during off-peak hours; and shall be stored in thermal storage tanks, to alleviate the added expense of demand charges (such as in conjunction with a heat pump system).

3) Safety disconnect switches shall be provided to disconnect power supply in the event of failure of the air-circulation fan.

h. **Heat Pump Heating Systems.** The main consideration in heat-pump design shall be to meet winter heating requirements with as small a heating apparatus as possible. When considering supplementary electricity for heat pumps, a thorough engineering analysis of available energy sources and systems is required. The most efficient method of using electric power for heating is the water-to-air heat pump; the air-to-air heat pump is second in efficiency; and the third is the water-to-water heat pump. The water-to-air pump shall be considered first. Heat pump systems may be provided, if approved by ARS; and, if analysis indicates that it is life-cycle cost effective.

1) **Water-to-air heat pump system** may be used for facilities with heat loads up to 100 tons. Internal heat of the building shall be used as a heat source.

2) **Air-to-air heat pump system** may be used for facilities with loads up to 100 tons. It is suitable when the heating outdoor design temperature is 17^{o} F or higher.

3) Added demand charges, as well as estimated power consumption and peak demands, shall be considered in the cost analysis. Where power suppliers use natural gas to generate more than 10 percent of the annual output, probability of increased fuel adjustment charges and increased maintenance cost shall also be considered.

4) For the air-to-air heat pump system, possible requirement for additional power transmission and substation capacity shall be considered.

5) To justify an electric heat pump system, annual owning and operating expenses during heating seasons shall be less than if heated by fossil fuel.

i. **Solar heating systems** convert solar radiation into a usable heating source. They may be active or passive systems with water on air used as the heating medium; and they may be used alone, or in conjunction with mechanical systems, depending upon design requirements, geographic location, and economic feasibility.

1) Solar heating systems shall be selected and designed in accordance with Department of Energy Facilities Solar Design Handbook.

2) A life-cycle cost analysis shall be conducted and the results shall be approved by ARS before the system is designed.

5.4.7 Air-Conditioning Systems. Air-conditioning systems shall maintain the space required by simultaneously controlling the supply air temperature, humidity, and distribution to the space. Following are the basic types of air-conditioning systems which shall be considered but not limited to:

a. **Self-contained systems** consist of a factory fabricated, packaged air-conditioning unit.

1) These systems may be used for any air-conditioning system where it is economically feasible.

2) These systems are less complicated to install, and have a lower first cost than other systems; they do not require central refrigeration equipment.

b. **Built-up systems** consist of individual components that are assembled at the building site.

1) These systems may be used as remote air-handling systems which use a central cooling plant.

2) These systems may reduce required capacity of the refrigeration plant due to load diversity. A central station refrigeration plant is usually remotely located and built-up units are more efficient, better constructed than self-contained units.

c. **Single duct systems** consist of an air-handling system and a one-zone duct system.

1) These systems are suitable for large open spaces which have uniform, substantially constant loads.

2) Modular equipment is permitted where part load performance could be improved, or where duct sizes are excessive.

d. **Constant Air Volume System.** In this system, outdoor and return air dampers are sequenced with the heating and cooling coils to satisfy space requirements. For a heating condition, the space thermostat controls the heating coil to achieve heating requirements; with rising outdoor temperature, the heating coil is closed off, and the outdoor and return air dampers are modulated to set point. On a further rise of outdoor temperature, after outdoor air damper is open, the cooling coil is modulated. When outdoor air requires more energy to cool than the return air, outdoor air is set at its minimum to provide ventilation.

1) This system is suitable where zone control is required such as auditoriums, meeting rooms, cafeterias, etc.

2) This system utilizes a mixture of outdoor air and return air to satisfy space heating/cooling requirements, without requiring additional energy.

e. **Multi-zone unit systems** may be classed operationally with single fan, and mixing of warm or cold air is done at the unit with a single duct running to the controlled space. Note that simultaneous heating and air bypass to provide zone control may be used.

1) These should be used in smaller areas where three to ten spaces need separate control. They are also suitable in fairly large buildings when multiple units are used with each unit serving several different zones. Application is limited only in hot-dry climates.

f. **Perimeter zone air systems** shall have a separate duct system that offsets the transmission load at the wall and glass. Solar load is assigned to the main air system. Perimeter system consists of a fan, a cooling coil, and heating coil. In operation, the outdoor thermostat resets supply fan discharge temperature on a preset schedule to balance heat transmission gains or losses at the exterior wall of the building.

1) These systems are suitable for seasonal cooling or heating or spaces where load transmission is at the wall and glass. They should be zoned, based on building exposure. If two units are used. they are zoned for south and west exposure on one unit, north and east on the other.

2) During unoccupied hours in the heating season, the fan operates on either a continuous or a cycling basis.

g. **Fan-coil system** with interior air supply is a combination air and hydronic system. This system cools or heats to compensate for transmission and solar variation and, in many cases, for part or all internal heat gain. The two-pipe system is a changeover system, where water coil receives chilled water in the cooling season and heated water in the heating season. This system can be four-pipe for certain special application.

1) An analysis of winter solar loads and control zoning is necessary for fan-coil systems. They are suitable when large ducts cannot be installed for security reasons or sensible and latent cooling requirements. Room unit systems shall not be considered where units would not be easily accessible for service or where drains cannot be installed. These units shall not be installed above ceilings. outdoor air shall not be taken directly from side by individual units. Ventilation air shall be introduced by a central air-handling unit(s).

2) These systems may be more economical for central systems, especially in spaces that require large ducts; or, spaces with high heat loads. Units shall be zoned by exposure and for changeover. Individual unit temperature control is possible. Provide condensation drains and pitch drain lines to the floor drain or service sinks.

h. **Heat pump systems** are as described in paragraph 5.4.6h.

5.4.8 Refrigeration Systems. These consist of a reciprocating compressor, a centrifugal compressor, a screw-type compressor, or an absorption refrigeration system. Following are the types of systems which are used for HVAC systems.

a. **Reciprocating Compressors.** Consist of factory components. Field-assembled units should be used only where flexibility cannot be obtained economically with a factory unit. These systems are suitable for use in direct or indirect expansion systems and are economically feasible in the range of 50-150 ton capacity.

b. **Centrifugal and Screw-type Compressors.** Utilize angular or screw-type momentum of a steadily flowing fluid to increase system pressure.

1) These systems may be used in a wide variety of refrigeration and air-conditioning systems and are suitable only for indirect expansion systems.

2) Centrifugal and screw-type compressors have greater volumetric capacities, size for size, and better efficiency, than do positive-displacement units.

c. **Absorption Refrigeration.** Heat-operated refrigeration system that requires medium or high temperature hot water or steam, or is gas fired.

1) These are suitable when live-cycle costs are lower than that of electrical compressors.

2) Consider the extra cost of owning and operating condenser water systems and savings in the cost of the foundation and the electrical wiring required for an absorption machine. If steam supply pressure is above that required by the absorption machine, cost of pressure reducing valves shall be included. Consider the cost of steam piping and condensate systems. These systems may have a higher steam consumption than steam turbine-driven centrifugal compressors, depending on turbine efficiency.

5.4.9 Ventilation Systems. Ventilation systems shall supply air to or remove air from a space to meet design criteria.

a. Mechanical ventilation shall be used where: (1) processes produce noxious or hazardous fumes; (2) dust or vapor creates unsafe or unhygienic conditions; (3) concentration of personnel in auditoriums or dining facilities required supply of outdoor air and removal of air; (4) odor removal from toilet rooms is required; (5) comfort of operating personnel in kitchens is required; and (6) electronic or electric equipment is in confined spaces and close control of operating temperature is required.

b. Spaces where exhaust systems are used to remove contaminated or hot air shall be maintained at a negative pressure to prevent exfiltration to other areas. negative pressure shall be created by exhausting 5 to 15 percent more air than the supply air. If anticipated fumes and vapors have a specific gravity greater than air, exhaust intakes shall be provided at the floor level.

c. Explosion-proof ventilation equipment shall be provided for areas where explosive vapors or dust are anticipated.

d. Filters shall be provided where particulate matter must be removed from the supply or exhaust air.

5.4.10 Evaporative Cooling System. Evaporative cooling is an adiabatic heat exchange system. Enthalpy of air remains constant, while dew point rises and dry-bulb temperature falls, to the loss of sensible heat that equals the gain in latent heat. These systems provide sensible cooling without controlling room humidity.

a. These are suitable where outdoor dry-bulb temperature is 93^{o} F or greater for more than 2,000 hours during the six warmest months of the year; or, where the wet-bulb temperature does not exceed 63^{o} F for more than 100 hours during the six warmest months of the year.

1) Actual evaporation rate and leaving air dry-bulb temperature depends on equipment saturation efficiency, which varies 70-95 percent, depending on equipment design.

2) Water flow of sprays over wetted surface shall be approximately 3 gallons per minute per c.f.m. of air flowing through it.

5.4.11 Air Cleaning Systems.

a. Air supplied to occupied spaces, equipment rooms, kitchens, cafeterias, etc., shall be provided with air filters, arranged to provide clean air at upstream side of air- handling units, fan-coil units, and heating units.

b. Filter efficiency shall be 50 percent minimum.

c. Filters shall be selected per ASHRAE Standard.

d. Select filter for operating velocity recommended by the manufacturer to give an economic combination of static pressure loss and dust holding capacity.

e. Minimum clearance of two feet shall be provided for service and inspection.

f. An access door with minimum width of 18 inches and an electric light in a watertight type fixture shall be provided.

g. Slope of connecting ductwork shall not be more than 15 degrees.

5.4.12 Humidification Systems. Humidity of a space depends on changes in moisture content of hygroscopic material in the space and the quantity and thermodynamic properties of air entering by infiltration or ventilation.

a. Winter outdoor conditions for most regions show moisture content of outdoor air to be relatively low even if the air is saturated. Therefore, to obtain humidities of 30 percent or above, it is necessary to add moisture to the air.

5.4.13 Piping Systems.

a. Hot and chilled water systems shall be of the two-pipe, reversed-return type. A direct return system may be used in special applications. Condenser water systems shall be direct return type.

b. **Sizes.** Size piping for maximum friction loss of 3.3 feet per 100 feet of straight pipe, or a velocity of 8 feet per second, whichever is larger.

c. **Valves.** Provide valves to isolate equipment (for operation and repair), including room units and individual risers to room units. Provide manual vents at high points hose type drain valves at low points, and both in sections or risers that can be isolated by valves.

d. **Supports and Expansions.** Show locations of expansion joints, loops, and anchors on drawings. Acoustical treatment to prevent transmission of vibration and fluid noise shall be incorporated.

e. **Flow Measurement.** Suitable devices shall be provided so flow can be measured in major equipment such as chillers, cooling towers, boilers, solar system loops, or other zones; e.g., primary and secondary loops. Balancing devices shall be provided to allow adjustment.

f. **Insulation.** Except for condenser water systems, piping systems shall be insulated. Systems exposed to weather or in tunnels shall be protected from freezing.

g. **Air Elimination System.** Compression tank(s) shall be provided for each closed system. Air-in-water system can cause serious problems, such as water hammer, noise, and excessive energy use.

h. **Make-Up Connections.** Each piping system shall be provided with a makeup water connection, for filling purposes, which shall comply with local codes.

i. **Pressure Drop.** Calculate and record for each piping system.

j. **Water Treatment.** Each closed/open piping system shall be provided with chemical treatment to inhibit corrosion, and bacterial scale, deposits, or growth.

5.4.14 Air Duct Systems.

a. Design Requirements

1) Equal friction method or static pressure regain method in the ASHRAE Fundamentals Handbook may be used to determine duct sizes.

2) Duct leakage rate shall not exceed 3 percent for low-pressure systems and 0.5 percent for medium- or high-pressure systems. (Note: For facilities involving work with hazardous materials, all ducts shall be constructed in a leak-tight manner with seams and joints usually welded airtight.)

3) Where ductwork is connected to equipment fittings such as heating coils, cooling or filters, transition should be as smooth. Slope of transition shall be 15 degrees on the upstream side and less than 30 degrees on the downstream side. Transitions in elbows shall be avoided.

4) Access doors or panels shall be provided in ductwork for any apparatus requiring maintenance, inspection, and service for:

a) filters
b) cooling coils
c) sound absorbers
d) volume and splitter dampers
e) fire dampers
f) thermostats
g) temperature controls
h) variable air-volume boxes
i) valves
j) humidifiers

b. **Elbows.** Smooth elbows with a center radius 1 ½ times the width of the duct should be used for rectangular ducts.

c. **Dampers.** Volume or splitter dampers shall be provided in ductwork, where necessary to obtain proper control, balancing, and distribution. An automatic parallel blade damper shall be used if position control is required. An automatic opposed blade damper shall be used if modulating control is required. Fire dampers shall be provided in accordance with NFPA standards.

NOTE: No dampers shall be used in chemical fume hood exhaust ductwork.

d. **Air Distribution Devices.**

1) Air outlets shall be located to provide proper throw, drop, and spread.

2) Air should not blow against obstructions such as beams, columns, lights or sprinklers, or on occupants.

3) Supply outlets shall be uniformly located within range of throw to distributed loads with air velocity at the occupant's level not exceeding 50 feet per minute (FPM).

4) Where loads are concentrated, supply outlets shall be located near load source.

5) Air terminals for variable air volume systems shall be selected to be compatible with characteristics of VAV box; i.e., outlet must be capable of performing at full and partial load. Flow pattern must be properly evaluated. Standard air outlets do not

perform satisfactorily with variable air-volume flows.

5.4.15 Chemical Water Treatment. Each piping system shall be chemically treated to prevent corrosion, scaling, and biological fouling deposits of piping systems and related equipment. Chemicals used depend upon local water conditions; analyses shall be done before selecting treatment. Cooling tower water (condenser water) and boiler feed water also require treatment.

5.4.16 Automatic Temperature and Humidity Control.

a. Automatic controls for temperature and humidity shall be provided for heating, ventilation, and air-conditioning systems. Provide controls to maintain dead band temperature ranges, to secure air-conditioning during periods of nonoccupancy, and to set back heating temperatures during periods of nonoccupancy. When smoke control is provided, controls and systems shall be coordinated. Controls may be pneumatic, electronic, electrical, or a combination of these, depending on application, availability of service, and cost. If the project has, or may have, a central control system, automatic controls shall be coordinated with the central system. Drawings shall delineate the pneumatic electronic, or electric type, with standard symbols, schedules, description of operation, sequences, throttling ranges, set points, etc. Show run thermostats on floor plans.

b. **Automatic Control Strategies.**

1) **Temperature.** Preheating and outdoor air dampering controls should prevent subfreezing air from entering downstream from the equipment.

2) **Humidity.** Controls should be modulating type, compatible with method of humidification used. Dew-point control is preferable; for spray-type equipment, locate sensor in tank. Provide controls to shut off humidifier when fan stops, or cooling is required, or to prevent overheating.

3) **Room Control.** For room temperature controls mount thermostats on permanent partitions or on columns. VAV units may have thermostats mounted above the diffuser.

4) **Refrigeration.**

a) Control air-conditioning units by room thermostat; where water-cooled, interconnect with condenser water pump so that it starts when compressor starts and stops when compressor stops.

b) On direct expansion systems, unless other protection is provided for short cycling, provide time-delay relays to prevent too frequent starting of compressor motors. Specify controls for plants with multiple compressors so that motors and capacity steps operate in a predetermined sequence.

c) Plants with individual refrigerating machines smaller than 500 tons should be operated by first starting the lead chilled water pump. Provide capacity controls in chilled water main to automatically start and stop machines in proper sequence and actuate capacity control of each machine.

d) Plants with individual refrigerating units larger than 500 tons should be controlled as in c) above, except that each machine must be started manually (either directly or through interlocks).

e) Locate thermostat for each cooling tower in outlet pump to start fan (or fans) in sequence. Solenoid valves in tower blow-down connections should be opened only when condenser pump operates. Provide thermostatically controlled bypasses for condenser water systems serving absorption machines. Consider means for reducing blowdown at low loads in localities with chronic water shortages, if economical.

f) In buildings with refrigerating units smaller than 500 tons, clocks or computer controls may be used to coordinate starting and stopping of refrigerating, air-handling, and ventilating equipment if significant savings result. Use separate controls for each buildings area diverse usage.

c. **Temperature Control Strategies.** Following are some of the operating control strategies which may be used where cost effective:

1) **Outside Air Temperature Cutoff:** Heating and refrigeration systems can be provided with an outdoor temperature sensing control which secures equipment when outdoor temperature falls within an adjustable number of degrees of the indoor temperature. Usually, this function is not required where an operating staff is

available.

2) **Warm-up Night Cycle:** Depending on climate conditions, thermal load imposed by outside air for ventilation may constitute a substantial percentage of total heating and cooling requirements. This function provides the capability of controlling outside air dampers when introduction of outside air imposes an unnecessary thermal load; e.g., when the building is unoccupied during warm-up or cool-down cycles. Outside air dampers would be closed during these times. This feature is appropriate for air-handling/ventilation equipment controlled for night setback, or for air-handling equipment designed for unoccupied heating of conditioning.

3) **Air Side Economizer:** Utilization of an outside air economizer cycle is a cost effective energy conservation measure. Such a system shall be provided, or an economic analysis shall be submitted to show that it is not cost effective. Outside air is used for all, or a portion, of the building's cooling requirements when monitored heat content of outside air is less than return air from the space. Heat content can be established through enthalpy sensor or dry-bulb thermostat. In climate zones where outside air is predominantly dry, a dry-bulb temperature economizer will prove effective and air preferred over enthalpy control, due to maintenance concerns.

4) **Space Temperature Night Setback:** During winter operation, energy required to maintain space conditions during unoccupied hours can be reduced by lowering the temperature set point for the space. Setback temperature is usually 10-15º F. This measure is cost effective, except in heat pumps. Heat pump auxiliary systems will be forced to operate in a setback warm-up condition that minimizes cost savings. Space temperature setback shall be applied, except for 24 hour use and heat pump designs, or an economic analysis shall be submitted to show that it is not cost effective.

5) **Chilled Water Reset:** Energy required to generate chilled water in a reciprocating or centrifugal electric driven refrigeration machine is a function of a number of parameters, including temperature of the chilled water leaving the machine. The higher the leaving water temperature, the lower the energy input per ton of refrigeration. Since chilled water temperatures are selected for peak design times, resulting temperatures can be elevated during most operating hours. Return air or selected zone humidity should be monitored for a high limit override. Automatic chilled water reset is inappropriate in climates of high humidity; where

humidity control is an issue; or where VAV systems are used. This function can be achieved by manual adjustment through an operating staff. In either case, manual or automatic, the chiller manufacturer should be consulted regarding safe limits for chilled water reset.

6) **Condenser Water Temperature Reset:** Another characteristic that affects energy input to a refrigeration system is the temperature of the condenser water entering the machine. Heat rejection equipment is designed to produce a specified condenser water temperature, such as 85º, at peak wet-bulb temperatures. Chiller efficiency will increase where lower condenser controls can be provided to optimize performance of the refrigeration system by resetting condenser water control when outdoor wet-bulb temperatures can produce lower condenser temperatures. Chiller manufacturer should be consulted regarding safe limits for condenser water reset.

7) **Outside Air Schedule Reset:** Hot water space heating systems, whether supplied by a boiler or a converter, are designed to supply heating requirements at outdoor design temperatures. Frequently, the hot water supply temperature can be reduced as heating requirements for the facility are reduced. For most facilities, this reduction is directly related to an increase in outdoor ambient temperature. Capability to reduce the temperature of supply water, as a function of outdoor to reduce temperature, will effect operating savings through reduced transmission (line) losses and improved heat transfer efficiency by the heating source. To accomplish this function, the temperature controller for the hot water supply is reset on a predetermined schedule as a function of outdoor temperature. This feature shall be provided to hydronic heating systems.

8) **Boiler Profile and Optimization:** The opportunity exists in certain applications of multiboiler heating plants to optimize selection of the most efficient equipment combinations to satisfy instantaneous heating requirements. Profiles can be developed for each heating unit by monitoring fuel input as a function of output. Based on the operating history developed, and the loads, boiler operation can be regulated to minimize energy input. This feature should not be applied unless required by design programming documents.

9) **Chiller Profile and Optimization:** This function is similar to the boiler profile described above. For multiple-chiller installations, operating load data is obtained

and applied to the manufacturer's predicted operating characteristics of each refrigeration machine. This, in turn, allows chillers to be cycled for lowest energy input. in some designs, the manufacturer's predictions can be refined based on a developed operating history. This type control has historically proven to be unreliable and should not be provided unless required by design programming documents.

5.4.17 Equipment Selection.

a. **Fans.**

1) Selection of fans shall be based upon the following:

a) Fans shall be selected to operate as close to the point of maximum efficiency as possible.

b) Fans should absorb the least brake horsepower for the given conditions of air flow and static pressure.

c) Fan outlet velocities shall not be less than the velocity of air in the duct for about four equivalent diameters downstream.

2) **Operation.**

a) Parallel operation of fans shall be avoided if possible.

b) If fans are selected for parallel operation, they should be backwardly inclined.

c) If fans are selected for parallel operation, each fan shall have self-closing or automatic discharge dampers to prevent backflow.

d) Fan motors shall be sized for individual operation with increased air flow against reduced static pressure.

b. **Central System Air-Handling Unit Requirements.**

1) Psychrometric study, with load calculations for each air-handling system should

show:

a) Outdoor and indoor design conditions.

b) Temperature rise in return (recirculating) air path, including ceiling plenums.

c) Temperature rise caused by fans.

d) Return and outside air mixture (coil entering) conditions.

e) Cooling and coil leaving (off-coil) air conditions.

f) Bypass and leaving air mixture conditions, where applicable.

g) System and lowest individual room sensible heat factor slopes.

h) Capacity of preheaters, cooling coil, heaters.

i) Room terminal temperature differentials.

2) Select off-coil conditions (psychrometric condition of air leaving cooling coil) to satisfy lowest sensible heat factor of the several spaces served. Air quantities for individual spaces are based on this off-coil condition, with adjustment for fan and duct heat gain being made to establish terminal temperature differential. Select the coils for face velocity between 400-500 feet per minute.

c. **Refrigerating Machines.**

1) **Type and Number of Units.** Refrigerating units in a plant should be of the same type. Design plant for minimum of two units that will carry the load and provide sufficient capacity reduction to permit continuous operation at minimum load.

2) **Chilled Water Requirements.** Arrange condensers and chillers for parallel flow unless series flow of chilled water is proved move economical. Flow diagram must be provided coordinating flow and temperature ranges of chillers and cooling coils; include hydraulic characteristics of the chilled water system and pumps.

3) **Energy Considerations.** Machine(s) selected shall be energy conserving. Specify controls for unloading the machine for peak load conditions. Energy

consumption per ton kw/hr. shall be specified; however, the kw requirements must be met by more than two major manufacturers.

d. **Cooling Towers.**

1) **General.** Provide mechanically induced draft cooling towers having a separate cell for each refrigerating machine. Each cell shall have a separate basin or a separate section of a common basin. Height of supports should permit easy maintenance and painting of basin and supporting structure. Outlet connections must be accessible for repairs.

2) **Tower Layouts.**

a) Size towers for heat rejection of system served and a 10^{o} F water temperature rise, and an 8^{o} F approach to entering wet-bulb temperature.

b) Design architectural enclosures and structural supports to accommodate both cross-flow and counterflow towers having any standard post spacing. Enclosures should not restrict air flow to tower or permit recirculation of fan discharge air.

PART 5. UNDERGROUND HEAT DISTRIBUTION SYSTEMS

5.5.1 **Scope.** This part of the handbook applies to design of distribution piping for supplying service from central generating plants to buildings and for service returns to plants.

5.5.2 **Exterior Distribution Systems.** Types of exterior distribution systems are:

a. **Steam.** System supplies heat in the form of steam from a central generating plant to several buildings or buildings groups for space heating, domestic hot water heaters, kitchen equipment, or other devices using steam, and returns condensate to the central plant.

b. **High-Temperature Water (HTW).** System circulates HTW which supplies heat from a central heating plant to several buildings for space heating and process work, and returns water to the central plant.

c. **Chilled Water (CHW).** System circulates CHW from a central refrigerating plant to several buildings for air-conditioning and returns water to the central plant.

d. **Cooling or Condensing Water.** System distributes cooling water from a central source such as a cooling tower, to several buildings for condensing steam or refrigerants. Water is then returned to the source (cooling tower).

5.5.3 Information Required for Design. Actual loads and conditions shall be determined on a case-by-case basis for each building.

5.5.4 Fluid Characteristics. Use sources below.

a. **Steam.** Criteria in Thermodynamic Properties of Steam (Keenan and Keyes).

b. **Condensate.** To determine cost of returning condensate, use the ASHRAE handbook and product directory.

5.5.5 Distribution Site Locations. When underground systems are to be used, thorough investigation shall be made of ground and water conditions. Consider the following:

a. Survey shall be made at a time of the year when the highest water table is expected.

b. Explorations (borings or test pits) shall be made at least every 100 feet along the line of a proposed system. If changes of stratification are noted, boring spacings shall be decreased so accurate horizontal soil profile may be obtained.

c. Explorations shall be extended 5 feet below expected elevation of a system to determine ground water conditions.

d. Particular attention shall be given to the following factors:

1) Surface runoff seeping into backfilled trench and percolating toward a system at a rate greater than the ability of the ground below the system to carry off the water.

2) Areas where a pond may develop, either along a sloping surface or in low flat areas.

3) In order to determine permeability of the ground below a system, see below.

e. **Field Permeability Test.** Permeability shall be tested as follows:

1) Tests shall be made along the line of a trench at intervals of approximately 100 feet, described below.

a) Holes shall be dug approximately 1 foot square to a depth of 2 feet below the approximate bottom of a trench.

b) Each hole shall be filled with water.

c) After seepage occurs, each hole shall be refilled immediately with water to the same depth.

d) If in 20 minutes or less water drops 2 inches, soil shall be considered dry; otherwise, consider it saturated.

2) Use test results as follows:

a) If soil is saturated, no further tests are required. Class A underground conduit systems for wet soils shall be used.

b) If soil is dry, permeability test holes should be deepened an additional 3 feet to determine if water table is within 5 feet of the trench bottom.

f. Soil resistivity shall be handled as follows:

1) If metal conduits are considered, soil resistivity readings should be taken along with conduit line.

2) A cathodic protection system shall be installed to protect metal conduits and manholes at sites where soil resistivity is less than 30,000 ohms per centimeter cube (ohm-cm), or where stray direct currents can be detected underground.

g. Soil stability shall be noted during above survey.

5.5.6 Economic Studies. Owning, operating, and maintenance costs, whether site is permanent or temporary, shall be considered. First choice should be given to an above ground system, which will be less costly.

a. **Annual Owning, Operating, and Maintenance Costs.**

1) Within limitations, lowest cost shall form the basis for selecting a distribution system and route, aesthetics notwithstanding.

2) Annual costs shall be based on 25-year retirement of installation costs.

3) Operation and maintenance costs depend on system design and experience of the operators.

b. **Aboveground and Underground Systems.** Permanent or temporary use, high water table, and degree of hazard shall be considered in selecting a system.

c. **Type of Underground System.** Suitability of systems should be considered.

d. Condensate return costs shall be calculated.

e. **High Pressure (above 50 psig) Steam Versus Low Pressure (0 to 15 psig) Steam Distribution.** Compare costs of high pressure pipe, valve, and fitting standards against low pressure standards, plus cost of pressure-reducing stations in selecting the most economical system. Medium pressure steam systems (15 to 50 psig), if economical, may also be used.

5.5.7 Piping Design.

a. **Sizing.**

1) **Equivalent Lengths of Piping.** Two straight lengths of pipe along a pipeline route, add lengths for valves and fittings as indicated in ASHRAE Handbook and product directory.

2) **Steam Piping.** Design considerations shall be as follows:

a) Steam flow charts for pressures of 30, 50, 100, and 150 psig, refer to ASHRAE Handbook. Charts show weight-flow rate, pressure drop, and velocities of saturated steam in Schedule 40 steel pipe. By selecting pipe size on an optimum pressure drop, total pressure drop of a pipeline may be estimated from an equivalent length.

b. **Pressure Reducing Valves.**

1) **Selection of Type.** Double-ported, pilot-operated valves shall be installed for capacities for inlet pressures above 125 psig. Double-ported valves do not shut off completely on no-load demand; therefore, single-seated valves shall be used for such service. Reducing valves shall not be installed according to pipe size (oversized valves do not give satisfactory service). Select valves to operate open, with ratings and reduction ratios recommended by the manufacturer. A strainer and condensate drain shall be installed ahead of pressure-reducing valves. Because volume of steam increases rapidly as pressure is reduced, a reducing valve with increased outlet or expanding nozzle shall be installed when reduction ratio is more than 15 to 1. Cutout valves shall be provided to isolate pressure reducing valve to perform maintenance. Manual bypass shall be provided for emergency operation when pressure reducing valve is out of service. Pressure gauge shall be provided on low pressure side.

2) **Safety Valves.** One or more relief or safety valves shall be provided on low pressure side of each reducing valve in case piping or equipment does not meet requirements of full initial pressure. Combined discharge capacity of relief valves shall be such that pressure rating of low pressure piping and equipment will not be exceeded.

3) **Capacity.** Where steam requirements are relatively large (above approximately 3,000 pph), subject to seasonal variation, two reducing valves be installed in parallel, and sized to pass 70 and 30 percent of maximum flow. During mild weather (spring and fall), the larger valve shall be set at reduced pressure so that it will remain closed as long as the smaller valve can supply the demand. During the remainder of the heating season valve settings are reversed.

c. **Takeoffs from Mains.** Buildings shall be at the top of mains, located at fixed points at or near anchor points. Where a branch is short, valves at each takeoff are unnecessary;

but, where valves are of considerable length, or where several buildings are served, takeoffs shall have valves.

d. **Condensate Returns.** Size condensate trap piping to conform with 30 to 150 steam piping per ASHRAE Handbook. Returns shall be as follows:

1) Discharge piping from condensate and heating pumps shall match pump capacities, which may be between 1 and 3 times the capacity of a steam system branch it serves, depending on whether intermittently or continuously operated.

2) Size common-pump discharge mains to serve the sum of its capacities. Use the Hydraulic Institute Pipe Friction Manual to select steel pump discharge pipe sizes for new clean steel pipe, allow 6 feet per second maximum velocity, and use a correction factor of 1.85 to prevent pressure loss as the pipe becomes roughened with age. Friction plus static heads shall not exceed ratings of standard pump and receiver units.

e. High temperature water (HTW) piping shall be as follows:

1) **Sizing.** Use pipe friction charts in the ASHRAE Handbook to select pipe sizes.

a) A reasonable average velocity is approximately 5 feet per second, minimum allowable velocity, 3 feet per second.

b) Friction charts are based on the rational flow formula using clean pipes.

2) **Venting and Draining.** Vent high points of distribution lines. Piping shall have drainage means at low points.

f. **Chilled Water.** Use standards of the Hydraulic Institute Pipe Friction Manual to size new pipe, unless water is replaced annually (a pressure or a correction factor of 1.41 shall also be used).

g. **Condenser Water.** Use standards of the Hydraulic Institute Pipe Friction Manual to select pipe sizes; and multiply pressure drop by a factor of 1.85 to allow for increased pipe roughness with age.

5.5.8 Piping Specifications.

a. **Steam Supply and Condensate Return.** Piping shall conform to ANSI B 31.1, Code for Pressure Piping, Power Piping; for underground prefabricated or pre-engineered systems.

b. HTW piping specifications and codes, except for underground prefabricated or pre-engineered types, shall be as follows:

1) **Piping.** HTW piping (450º F maximum) shall conform to ANSI B 31.1 Standard Code for Pressure Piping and Power Piping.

2) **Joints.** Use welded joints throughout. Hold flanged joints to a minimum and use ferrous alloy gaskets in joints. Do not use copper or brass pipe.

3) **Valves.** Valves shall have cast-steel bodies with stainless steel, no bronze, trim and shall be capable of being repacked under operating pressures. Use gate valves only as shutoff or isolation valves.

c. **Chilled and Condenser Water.** Use Schedule 40 steel pipe in 10-inch sizes and smaller; use 0.5-inch wall thickness steel pipe for 12-inch size or larger.

5.5.9 Flexibility and Allowable Bending Stresses. Piping shall be as follows:

a. **Control of Expansion.** Where possible, provide for expansion of pipes by changing direction of pipe runs or by using expansion bends.

1) **Expansion Joints.** Where space restrictions prevent the above, expansion joints shall be installed in accessible locations.

2) **Branch Lines.** Where practicable, piping shall be designed to provide for expansion of branch lines inside buildings and shall not affect mains.

b. Expansion bends shall be factory fabricated.

1) Loop sections shall be furnished to make delivery and handling easier.

2) **Anchors.** A reasonable distance between anchors for expansion loops is 200 feet.

3) **Cold Springing.** This may be used in installations but no design stress relief shall be allowed. Refer to ANSI B 31.1.

c. Expansion joints shall be one of the types below.

1) **Mechanical Slip Joint.** An externally guided joint designed for repacking under operating pressures. Maximum traverse of piping in expansion joints shall be under 8 inches.

2) **Bellows Joints.** Use these for thermal expansion, with stainless steel bellows, installed according to manufacturer's instructions. Corrugated bellows for absorbing vibration of mechanical movement at ambient temperatures may be made of copper or other suitable materials. Maximum travel of 4 inches shall be allowed.

3) **Flexibile Ball Joints.** These shall be installed according to manufacturer's instructions.

d. **Flexibility Analysis.** See Section 6 of ANSI B 31.3 for expansion and flexibility criteria, and allowable stresses and reactions.

1) For methods of analyzing stresses in piping systems use piping handbooks and publications of pipe and welding pipe fitting manufacturers. Manufacturers also supply calculation forms and charts.

2) Keep calculated pipe stresses under those allowed by ANSI B 31.1.

5.5.10 Drainage Provisions. Drainage shall conform to requirements listed below.

a. **Pitch.** Use and surrounding terrain affects the pitch of piping as below.

1) **Steam Piping.** Piping shall be pitched down at a minimum of 3 inches per 100 feet of length in the direction of steam flow and condensate flow.

2) **Underground Piping.** Where ground surface slopes in the opposite direction to

steam piping, step up underground piping, using vertical risers at drip points in manholes and pitch them down to the next drip point. This method should also be used for very long horizontal runs, above or below ground, to keep piping within a reasonable range of elevation.

3) **Counterflow.** Where counterflow of condensate within steam pipe may occur because stepped construction cannot be built, or steam flow is reversed in a loop system, that portion shall be pitched up in the direction of steam flow a minimum of 6 inches per 100 feet. Pipe diameters shall be increased by one standard pipe size.

4) **Compressed Air and Fuel Gas Lines.** Pitch compressed air and gas piping in the same manner as steam piping.

5) **Pumped Water Pipe.** Pitch these pipes (condensate, HTW, CHW, or condenser water) up or down in direction of flow. Drain valves shall be placed at lower points.

b. **Drips and Vents.**

1) Drip legs shall be provided to collect condensate from steam piping and compressed air piping for removal by automatic moisture from steam piping and compressed air piping for removal by automatic moisture traps, or by manual drain valves for compressed air piping, when practicable. Drip legs shall be at low points, at bottom of risers, and at intervals of approximately 200-300 feet for horizontally pitched pipe where a trap is accessible, or not more than 500 feet for buried underground pipe systems.

2) **Water Piping.** Piping, especially high temperature water piping, shall be vented at distribution high points.

c. **Condensate Piping.**

1) **Drip Traps.** Furnish a complete system of drip traps and piping to drain steam piping of condensate from drip legs. Drip piping to traps shall be the same weight and material as drained pipings.

2) **Traps.** A trap may be discharged through a check valve into pumped condensate

line if pressure in trap discharge line exceeds the back pressure in condensate line during standby or an intermittently operated pump. Preferably, a condensate line from a trap should run separately to a gravity condensate return main or to a nearby flash tank.

3) **Trap Discharge Piping.** Piping shall be pitched down a minimum of 3 inches per 100 feet to collecting tank of a condensate pump set or to a gravity return, unless there is sufficient pressure in a steam line to overcome friction and static head whether level or pitched up.

5.5.11 Anchors and Supports.

a. **Anchors.**

1) **Location.** Locate anchors at takeoffs from main and other points that contain pipeline expansions. If possible, anchors should be located in buildings, tunnels, and manholes with access provided.

2) **Design.** Anchors shall be designed and located in accordance with ANSI B 31, Code for Pressure Piping.

3) **Strength.** Anchors shall be strong enough to withstand expansion. With expansion joints, additional reaction to internal fluid pressure shall be considered.

4) **Guying.** On aboveground systems at high elevation, ends of structural steel anchoring pipes to poles shall be guyed parallel to pipeline in both directions to concrete deadmen by wire rope and turnbuckles, if necessary.

5) **Embedding.** In underground concrete trenches, ends of structural steel shapes anchoring a pipe may be embedded in trench walls or floors.

b. Supports shall conform to ANSI B 31, Code for Pressure Piping.

1) **Low Elevation.** For aboveground systems at low elevation, concrete pedestals, steel frames or treated wood frames may be used and spaced, depending on pipe sizes.

2) **High elevation.** At higher elevations, pipelines may be supported on wood, steel pipe, H-section steel, reinforced concrete, pre-stressed concrete, poles with crossarms, or steel framework fitted with rollers and insulation saddles. Depending on site conditions details will vary.

3) **Long Spans.** When these are necessary, cable-suspension or catenary systems may be used with supports up to four feet apart.

4) **Underground Conduits.** Supports for underground conduits shall be manufacturer's standard design.

5.5.12 Distribution Circuits and Routes. Select a type of circuit that is economical; easy to operate, balance, and control; and is suitable for the terrain. Circuits easiest to balance and control are those where pressure and temperature differences are fairly constant between supply and return branches. Distribution routes for piping shall conform to the following:

a. **Preliminary Planning.** The following factors shall be considered.

1) **Alternate Routes.** Plan several alternate, direct routes for each service pipeline from its source to load delivery center, allowing for future expansion.

2) **Pressure Drop.** From allowable pressure drop and final length of the line, determine pressure drop per 100 feet. note maximum flow between each load center and size different pipe sections accordingly.

3) **Obstacles.** From a field survey, note obstacles for each route.

4) **Economy.** Select the route economically justified. Make full use of basements, crawl spaces, and attics; connecting corridors between buildings; and tunnels and concrete trenches. High-pressure fuel gas, steam, and HTW piping inside buildings should be avoided where safety is reduced.

5) Future buildings should be considered and a route planned that will easily supply them.

b. **Piping Layouts.** Piping shall be planned and positioned as below

1) **Parallel Piping.** Determine which lines between same points should parallel each other (such as supply and return), or should be separate (such as steam lines separate from chilled water lines). Minimum clearance between conduits in a trench should be 6 inches.

2) **Location.** Determine locations of expansion bends or loops, anchors, takeoffs, and drip points.

3) **Map.** Lay out each pipe system on a scaled contour map of the site and on a profile drawing of the route. Indicate obstructions such as streams, roads, railroads, buried tunnels, concrete trenches, drainage, piping, sewers, water piping, electrical conduits, manholes, and other service piping.

CHAPTER 6. ELECTRICAL SYSTEMS
PART 1. GENERAL

6.1.1 **Scope.** This chapter presents data and considerations necessary for proper design selection of electrical power source and distribution systems. The criteria covers load estimating factors, electrical power sources, distribution systems, illumination, communication, signaling, special equipment, and repair and alterations for ARS buildings.

6.1.2 **Policies.**

a. **Local Codes.** Design and installation of interior lighting, electric power facilities, and roadway lighting systems should conform, as far as practicable, with adjoining community regulations and standards.

b. **Design Analysis.** Design analysis covering electrical systems shall be made in accordance with good design procedures based on conservation of energy, and shall show all calculations used in determining capacities and ratings of components of electrical systems. Methods and tabulations used in sizing conductors, raceways, and protective devices, and other equipment necessary to complete a system which requires other than routine methods, shall be included. Equipment of at least three manufacturers shall be capable of being installed, serviced, maintained, and replaced in the space available.

6.1.3 **Codes and Standards.** Codes, standards, specifications, etc. used as the basis of design shall be the latest editions including amendments, or revisions. Work not described in this chapter shall be accomplished in accordance with the following applicable publications:

a. National Fire Protection Association (NFPA)/ National Electrical Code (NEC).

b. National Electrical Manufacturers Association (NEMA).

c. Institute of Electrical and Electronic Engineers (IEEE).

d. Edison Electric Institute (EEI).

e. Insulated Power Engineers Association (IPEA).

f. American National Standards Institute, Inc. (ANSI) and ANSI C-2, The National Electrical Safety Code.

g. American Society for Testing and Materials (ASTM).

h. Underwriters Laboratories, Inc. (UL).

i. Illuminating Engineers Society (IES).

j. Rules and Regulations of the local electric companies.

k. ANSI/ASME Elevators and Escalators Safety Code A17.1.

l. Occupational Safety and Health Administration (OSHA) Regulations.

6.1.4 Coordination. The electrical design shall be coordinated with the architectural, structural, and mechanical designs. On alterations projects, the A-E shall make such visits to the site as are necessary to ensure coordination with existing work.

6.1.5 Economic Design.

a. **General.** Electrical systems shall be designed to permit acceptable competitive bids. Equipment and systems shall be efficient and economical in construction, operation, and maintenance.

b. To avoid excessive initial cost, keep the number of circuits to a minimum without compromising the final size of the feeder or voltage drop of primary feeder.

c. Where a group of large motors is to be served by a distribution system, establish the most economical voltage for the common size motor, and adopt a voltage for distribution.

6.1.6 Economic Analysis. The A-E shall perform an economic analysis of power sources to determine the optimum scheme. The following factors shall be considered:

a. Primary versus secondary metering.

b. Government-owned versus electric utility-owned transformers.

c. Use of medium-voltage motors for large equipment, such as compressors, pumps, etc.

d. Frequency of service interruptions to the extent that they affect the selection of equipment.

e. Amortization costs for replacements or additions.

f. Individual versus combined metering.

g. Cost of power factor correcting capacitors where rate schedules penalize low power factor.

6.1.7 **Construction Documentation.** Submission shall include the complete drawings, fully developed project specifications, design calculations, analyses, and other required documents.

6.1.8 **Project Specification.** Specification shall include sizes, capacities, and electrical characteristics of major electrical equipment. Such information shall be indicated on working drawings.

6.1.9 **Manuals.** Operating and maintenance manuals shall be provided for each of the following classes of equipment:

a. Electrical systems (switchgear, control panels, etc.).

b. Special systems (sound, fire alarm, etc.).

c. Emergency systems (generator, battery, etc.).

6.1.10 **Design Calculations.** Load demand, voltage drop, short-circuit, and motor starting calculations shall be prepared for feeder and typical branch circuits to substantiate design.

a. **Building Load.** Building feeder load calculations shall include requirements for:

1) Power (equipment receptacles)
2) Lighting
3) HVAC
4) Miscellaneous loads
5) Special loads (elevators, food service, computer rooms, etc.)
6) Spare capacity.

b. **Short-Circuit Coordination Study.** Short-circuit and coordination studies for three-phase and single-phase-to-ground faults shall be made to select properly rated equipment and protective devices for the fault currents available. Overcurrent and other protective devices shall be selected and set to provide proper selectivity and protection. Coordination shall be achieved with the source supplying the building or facility and extend to all the downstream devices.

1) Fuse Coordination. Fuses must be coordinated with all other circuit protective equipment in the system. Use time-current curves of all devices in the system, from the source to the fuse.

2) Provide coordination of the ground fault devices and components to insure selective tripping of devices and components.

3) Electric Utility Coordination. Design and construction of the primary distribution system shall be coordinated with the requirements of the electric utility. Design drawings, specifications, and shop drawings shall be submitted to the electric utility for review. Obtain approval in writing from the utility indicating electric utility concurrence with coordination.

4) Specify that contractor must complete and provide a report on the short-circuit and coordination study or power system analysis by a qualified professional engineer experienced in this work. The report shall include, but not be limited to, all calculations, relay, breaker, and/or fuse set values and curves for each system configuration, nondescripts testing of system to insure conformance, and coordination of ground fault devices and components.

c. **Voltage Drop.** Calculations shall be made for feeders, unusually long branch circuits, and large motors under starting conditions. Calculations shall show each significant motor kVA inrush requirement in comparison with electric utility limitations, and resultant starting voltage drop at the associated switchgear assembly that serves lighting feeders. The starting voltage should not cause a voltage drop of more than 2 percent at lighting feeder in switchgear assembly.

d. **Lighting.** Calculations shall be made for each significant area. Calculations shall follow the IES Lighting Handbook; point-by-point calculation of nonuniform task-oriented office lighting may be done by computer.

PART 2. PRELIMINARY DESIGN CONSIDERATION

6.2.1 Preliminary Data.

a. **Load Data.** Before specific power sources and distribution systems can be considered, realistic preliminary load data, including master planning requirements, shall be compiled. Expected power demand on intermediate substations and on main power supply should be calculated from connected load layout. Determine these factors by load analysis and by combining loads progressively. To combine load, start at ends of smallest feeders and work back to power source. Preliminary estimates of lighting loads may be made by assuming watts per square foot of building area.

b. **Load Analysis.** Analyze characteristics of each load to determine appropriate load estimating factors. Consider items such as environmental conditions of weather, geographical location, and working hours, as the situation dictates.

6.2.2 Estimation of Loads.

a. **Individual Loads.** Individual loads are those with one incoming service. In general, these loads would comprise single structures.

b. **Lighting Load.** Divide facility area into significant components by function. Determine average lighting level and type of light source for each area.

c. **Power load.** Power load shall include loads other than lighting loads and those served by general purpose receptacles.

d. **System Loss.** System loss of approximately 6 percent, based on calculated maximum demand, shall be added to the building load.

e. **Load Growth.** Determine requirements for load growth for anticipated usage and life expectancy with particular attention to possibility of adding heavy loads in the form of air-conditioning, electric heating, electric data processing, and electronic communication equipment. Before determining the size of service and method of distribution to a facility, an economic analysis shall be made to determine the most feasible way of serving this future load.

f. **Emergency Loads.** Determine emergency power requirements based on three types of loads:

1) Minimum essential load.

2) Emergency load for vital operations.

3) Uninterruptible (no-break) load.

When the three categories of emergency power requirements have been ascertained, determine where local emergency facilities are required, where loads may be grouped for centralized emergency facilities, and what loads are satisfied by the reliability of the general system.

g. **Area Loads.** Area loads consist of groups of individual facility loads served by a subdivision of the electrical distribution system. The term area applies to the next larger subdivision of an overall distribution system. Demand loads for an area must be known for sizing the distribution wiring and switching.

6.2.3 Selection of Power Source.

a. **Primary.** The primary source shall have sufficient capacity to provide for peak electric power demand during normal operations.

b. **Standby.** The standby source shall have enough capacity so that it alone can supply minimum essential operating electric load of the building and, when added to capacity of primary source, will provide a combined capacity sufficient to furnish the estimated peak demand under mobilization conditions.

c. **Emergency.** Emergency sources, usually one or more engine-driven, manual or automatic-starting emergency generators, shall have sufficient total capacity to provide electric power demand for vital operations. Vital operations permit power interruption only for relatively short durations. The emergency source shall have

sufficient capacity to provide continuous adequate supply for vital operations.

6.2.4 Uninterruptible (No-Break) Power. A power system is necessary for certain research activities, critical electronic equipment, or computer rooms with functions that require a continuous power supply. This power system is defined as one that, under all conditions, will provide suitable power to a critical load without interruption. The no-break system must be capable of supplying power of suitable quality during voltage fluctuations or surges, or fault or ground conditions. Successful operation of critical spares depends on power system reliability. In designing no-break Uninterruptible Power Supply (UPS) systems, it is important that the system be as simple as possible, using basic applications of power system design practices which have been proven sound and economical for the purpose on a life-cycle basis.

6.2.5 Installation of Distribution System.

a. **Overhead Method for General Application.** Overhead lines shall be avoided.

b. **Underground Methods.** This method shall be used if normal conditions exist.

6.2.6 Grounding of Distribution Systems. Solid grounding shall be used for automatic clearing of ground faults. Use only on secondary systems or where impedance of transformers is included in zero-sequence path. This connection shall be avoided for grounding of generators where single-phase fault current at terminals will exceed three-phase fault current for which they have been braced.

PART 3. SERVICES

6.3.1 Service Selection. Selection of service characteristics shall be based on the economic analysis.

6.3.2 Service Characteristics.

a. **Primary service.** Where primary service is selected, three-phase service should be provided, and any voltage class of 34.5 kV or less may be used.

b. **Secondary Services.** Secondary service shall be either 208Y/120 volt or 480Y/277 volt, three-phase, 4-wire service.

c. **Metering.** Regardless of operating agency, buildings shall be provided with a revenue primary or secondary metering installation ahead of the main disconnecting device.

d. **Service Equipment.** Locate equipment at service entrance point. Use circuit breakers. Select the most economical devices to accommodate short-circuit and normal current requirements.

e. **Short-Circuit Considerations.** Devices must be able to clear any fault on secondary systems without damage when service conductors are connected to low-voltage network systems, wherein service protective devices and entire utilization system shall be subjected to large short-circuit currents.

6.3.3 Service Equipment Rooms. Utilities shall be accessible, and equipment rooms shall be sized to provide sufficient space for maintenance. If electrical equipment is located in an electrical-mechanical equipment room, adequate space for electrical equipment shall be reserved.

6.3.4 Vaults for Utility Transformers. If space conditions require that the electric utility's transformers be installed on Government property, they nay be pad-mounted outside the building, or installed in vaults within the building. Vaults shall be constructed as part of the building and shall meet the utility's requirements.

6.3.5 Service Feeders.

a. **Number.** The number and arrangement of incoming feeders shall be based on requirements for maximum uninterrupted service, large motor inrush characteristics, and the reliability of the distribution system.

b. **Capabilities.** Electrical rating of each service feeder shall be based on the sum of distribution feeder requirements, future loads, and system demand and diversity factors. Neutrals of secondary services shall be full size, where required, to carry electrical discharge lighting, data processing, or similar equipment loads where there are harmonic currents present.

6.3.6 Service Feeder Conduits. Conduits for service feeders shall be extended underground from the point of connection with the electric utility's system to the exterior wall of the room or vault in which main service disconnecting equipment is located.

6.3.7 Service Disconnecting Equipment.

a. **Primary Disconnecting Equipment.** For projects having only two incoming feeders, each feeder shall be provided with a metal-enclosed interrupter switchgear assembly. Each feeder shall supply two unit substations. Interrupter switchgear for a single incoming feeder may be combined with the unit substation.

b. **Secondary Disconnecting Equipment.** Service disconnecting devices shall be low-voltage power circuit breakers or molded case circuit breakers. Power circuit breakers shall be used for secondary services that have ratings in excess of 600 amperes.

c. **Ratings.** Continuous current ratings of service disconnecting devices shall be calculated on the same basis as the capacities of the feeders they serve. Interrupting capacities of disconnecting devices shall be not less than the fault currents available at the point of application.

6.3.8 Electric Utility Equipment. Service equipment to be furnished and/or installed by the electric utility shall be shown and identified on drawing and listed in specifications. Each point at which material furnished by the utility terminates or is connected to material furnished by the construction contractor shall be clearly specified or shown on drawings.

6.3.9 Ground Fault Protection.

a. **Application.** Ground fault protection (GFP) shall be applied as required by the NEC. Additional GFP shall be required on feeder and branch circuits on two levels to achieve selectivity and continuity of service.

b. **Selection.** Economics shall be balanced against the cost of outages and potential cost of research loss or equipment damage to arrive at a practical system. Each system shall be analyzed individually. The following factors shall be considered in selecting GFP.

1) Type of power distribution.

2) Reliability required.

3) Neutral circuit complexity.

4) Number of ground return paths.

5) Rating and application of protective devices.

6) Setting of protective devices.

c. **Special Considerations.** Particular care in the application of GFP systems shall be taken when there are a number of ground return paths to the service transformer via building steel and earthground. GFP equipment shall be desensitized by fault current flowing directly to the transformer. Solutions to the desensitizing problem follows:

1) Use of zero-sequence ground sensor encircling the phase and neutral conductors.

2) Use of residually connected individual sensors on each phase and neutral conductor to detect current imbalance.

3) Isolation of equipment grounds from building steel and earth ground (except at service).

4) Source ground current transformers (on neutral).

d. **Systems.** The two commonly used systems are:

1) Residually connected.

2) Zero-sequence.

e. The type of system far a project shall be determined by the factors in b and c above, and circuit breaker coordination calculations.

PART 4. ELECTRICAL EQUIPMENT ROOMS

6.4.1 **Planning.** Separate electrical rooms shall be provided for medium-voltage and low-voltage switchgear assemblies and for power, distribution, and substation transformers. Rooms shall be located where they will be readily accessible, but free from the danger of flooding. They shall not be located immediately below or opposite building entrances, in areas that require sump pumps for drainage, or in sub-basements more than one floor below street level. Each room shall be provided with an appropriate number (regarding fire safety) of exit doors with panic hardware which shall open into space that is accessible at all times. Exit doors shall not open into stairways, toilets, gear rooms, or shop spaces that may be locked.

6.4.2 **Clearances.** Clearances and spacing of electrical equipment shall conform with the requirements of NEC. Aisle widths shall be increased wherever necessary for the use or storage of breaker removal equipment.

6.4.3 **Concrete Curbs.** Continuous concrete curbs shall be provided around each liquid-filled transformer or group of transformers. Curb height and area enclosed shall be adequate to contain the liquid from the largest transformer in the group in the event of tank rupture.

6.4.4 **Equipment Removal.** Rooms and adjoining areas shall include clearances, suitable doors, removable windows, panels, or other means to allow electrical equipment to be removed and replaced. Arrangement shall permit these operations without cutting or removing walls, floors, structural members, and other equipment. Equipment shall be installed in sections or subassemblies where it is impossible to provide other means for removal. This requirement shall be defined in drawings and specifications. Also, floor loading and access to building exit by vehicles shall be considered and specified.

6.4.5 **Lighting.** Normal room lighting shall be described in Part 10. Provide an exit sign over the exit door and emergency lights with a minimum of one foot-candle illumination. Lights for electrical and mechanical rooms shall be connected to the emergency generator, if available, or shall have 90-minute battery backup.

6.4.6 **Ventilation.** Provide a thermostatically controlled exhaust fan to remove heat buildup. Where possible, makeup air shall be obtained directly from the outside. Provide fire dampers as appropriate to maintain fire rating. Coordinate requirements with the mechanical design.

PART 5. PRIMARY DISTRIBUTION SYSTEM

6.5.1 **General Description.** The primary distribution system shall consist of Government-owned incoming feeder conduit banks, medium-voltage metal-clad switchgear, distribution feeders and raceways, substations, and auxiliary switchgear and secondary unit substations shall be substituted for the corresponding equipment items indicated above.

6.5.2 **Distribution Feeders.** The capacities of medium-voltage distribution feeders shall be determined on the same basis as primary service feeders. A separate feeder shall be provided for each transformer in a primary substation. Feeders supplying secondary substations may serve more than one transformer, provided continuity of service is not impaired.

6.5.3 Feeder Raceways.

a. **Electrical Equipment Spaces.** In electrical equipment rooms, electrical closets, and similar spaces, medium-voltage distribution feeds shall be installed in galvanized steel conduit, and horizontal runs shall be overhead. However, cable trays may be used to support medium-voltage distribution feeders in electrical equipment rooms. Exposed power cables shall be fireproofed throughout. Top connections shall be provided to the transformers and switchgear assemblies.

b. **Risers.** Conduits for medium-voltage feeder risers shall be galvanized steel. When they are not in electrical closets, electrical equipment rooms, or transformer rooms, each conduit or group of conduits shall be protected as required by the NEC.

c. **Structural Coordination.** Design of interior and exterior medium-voltage distribution systems shall be coordinated with the structural design features to ensure that structural drawings show all details of supports, reinforcement, dowels, etc. required for a satisfactory installation.

6.5.4 Primary Substations.

a. **High Voltage.** Where primary service voltage exceeds 15 k/v, a primary substation shall be provided by the electric utility to reduce the voltage. The substation shall be of joint use and may include the Government-owned, medium-voltage metal-clad switchgear required for the site distribution system. The firm capacity of the substation shall be determined by the electric company.

b. **Medium-Voltage.** Primary substations shall be provided where required to supply power for large medium-voltage motors, such as those driving air-conditioning compressors and pumps. Outgoing distribution voltage shall be 4.16 kV. The firm capacity of each substation shall be equal to the sum of the kVA ratings of the medium-voltage motors served at a demand factor of 100 percent. Total transformer capacity provided shall equal, or exceed, the calculated firm substation capacity, but shall not include reserve capacity.

6.5.5 Secondary Substations. Secondary substations shall articulate unit type, consisting of a transformer and primary metal-enclosed interrupter switchgear and secondary switchboard. Where a project requires a single unit substation served by a single medium-voltage feeder, the service disconnecting and metering equipment shall be integrated with the primary switchgear. Where two primary feeders serve two unit substations in the same location, they shall be arranged for secondary selective operation; but shall not be double ended unless specified.

6.5.6 Batteries. Those projects requiring high-voltage or medium-voltage circuit breakers shall be provided with a 125-volt DC storage battery bank. Each bank shall be monitored so that an alarm will sound when the voltage falls below that required to operate the trip coil. Power shall be provided to circuit breakers, as described in a through d below, for operation of breakers.

a. Battery bank shall be of the nickel-cadmium, lead-acid, or lead-calcium type.

b. Battery bank shall have capacity to carry continuous loads (relays, indicating lamps, etc.) for 8 hours and perform either the tripping or the closing operation described below with the charger de-energized and a final voltage of not less than 105 volts. Simultaneous tripping of breakers in the primary system shall be required. Closing operation shall require closing the largest single breaker, if the installation contains fewer than four circuit breaker. Breaker closing current shall include spring release coil current and starting current of the spring charging motor.

c. Ratings for batteries shall be obtained by assuming that duration of the tripping or closing load is one minute, and adding the equivalent of the continuous load for 8 hours. A safety factor of 1.80 shall be applied for small projects, and a safety factor of 1.40 for large projects.

d. Each battery bank shall be provided with static charging equipment fed from an emergency panelboard. Battery bank and charging equipment shall be installed in, or near, the medium-voltage switchgear room. Batteries, racks, charging equipment, auxiliaries, etc. shall be shown on drawings. Adequate space for maintenance shall be provided.

6.5.7 Unit Substations.

a. **Primary.** Primary unit substation shall consist of a primary terminal chamber, a three-pole, three position disconnecting and grounding switch, a power transformer, and an outgoing feeder section close-coupled as an integrated unit. Primary terminal and switch chambers shall be welded to transformer enclosures or tank. Transformer shall be a dry type or a high-fire point, liquid insulated type. Outgoing feeder section shall be contained in a suitable steel housing welded to the transformer enclosure or tank. Space shall be provided within the housing for the fused potential transformer required for metering and control. Primary terminal chamber and the outgoing feeder section housing shall be arranged for top connection of the feeder conduits.

b. **Secondary.** Secondary unit substation shall consist of a medium-voltage fused load-interrupter switch, a transformer, a low-voltage section, and necessary transition sections close-coupled as an integrated unit. Primary service disconnecting and metering equipment shall be included where required. Transformer shall be either high-fire point, liquid-insulated, or ventilated, dry type. A ventilated, dry transformer shall be used only when the rating does not exceed 500 kVA, where dust and moisture conditions are favorable, and where the sound level will not be objectionable.

PART 6. SECONDARY DISTRIBUTION SYSTEM

6.6.1 **General.** Wire and conduit size shall be based on use of copper conductors. Aluminum conductors are not acceptable. Insulation shall be rated 75^{o} C or more in areas subject to abnormal heat, such as boiler room.

a. Where 480Y/277-volt, three-phase, 4-wire service is provided for fluorescent lighting and power, dry type transformers shall be installed to provide 208Y/120-volt current for incandescent lighting, receptacles, small motors, etc.

b. Motors smaller than 1/2 horsepower may be connected to 120-volt single-phase circuits. One-half horsepower and larger motors shall be connected to three-phase circuits, except where single-phase motors are furnished as standard factory assembled parts of machines, such as kitchen equipment and window-mount air-conditioners.

c. Feeders supplying all, or part, of the electrical power or service to laboratories shall contain a separate green insulated grounding conductor sized in accordance with the NEC.

6.6.2 Low-Voltage Switchgear Assemblies.

a. **General Requirements.** A low-voltage switchgear assembly (dead-front switchboard or metal-enclosed power switchgear) shall be provided for each building and secondary substation that requires secondary service rated more than 600 amperes. Secondary service disconnecting devices and metering equipment, where required, shall be included in main switchgear assemblies. Each switchgear assembly shall include a circuit breaker for each outgoing feeder. Devices shall be the drawout type.

b. **Types.** Switchboard shall be enclosed, dead-front. Low-voltage metal-enclosed switchgear assemblies with low-voltage power circuit breakers may be used when the total load exceeds 2,000 amperes.

c. **Expansion.** Each low-voltage switchgear assembly equipped with circuit breakers shall be provided with one spare circuit breaker and two spaces (completely equipped compartments without breakers) for accommodation of future loads. Ratings of spare breakers and future breakers shall be indicated on drawings duplicating ratings of active breakers. Where known loads are anticipated in the near future, spare units all be provided. When possible, switchgear assemblies shall be arranged so that additional units may be installed.

6.6.3 Overcurrent Protection. Short-circuit protective devices shall provide continuity of service, and short-circuit ratings shall be based on values resulting from system coordination. Selection of overcurrent protective devices for low-voltage switchgear assemblies shall be made on the basis of load current, available fault current, and selective operation.

a. **Low-voltage Power Circuit Breakers.** Breakers with drawout mountings in metal-enclosed switchgear shall be used when trip rating is above 200 amperes. Where interrupting capacity of the breaker alone is inadequate or where cost of a breaker of adequate interrupting capacity is not justified by service requirements, breakers and high-interrupting-capacity current-limiting fuses may be used in combination.

b. **Molded-case Circuit Breakers.** Breakers with fixed mountings may be used in switchboard when trip ratings are not over 800 amperes and their interrupting capacities, with or without current-limiting devices, are adequate. Molded-case circuit breakers shall not be connected to buses of a metal enclosed switchgear assembly consisting mainly of low-voltage power circuit breakers. When molded-case breakers are used for a switchgear assembly, they shall be segregated on a separate switchboard section or panelboard section having its own buses fed through a low-voltage feeder breaker.

c. **Switches.** Place switches where necessary for isolation purposes. To determine switch ratings, follow the procedure outlined for circuit breakers. Switches shall be derated to 80 percent of maximum capacities.

d. **Fuses.** Locate fuses where required to protect low voltage signaling and control circuits against overloads or short circuits. Determine rating of fuses, based on voltage, current carrying capacity, and interrupting capacity. Take into consideration all forms of inrush current.

6.6.4 **Motor Control Centers.** Motor control centers (MCC) with NEMA Class I Type B wiring and combination motor starters and current breaker disconnects shall be provided, in lieu of separately mounted motor starters, where several motors are located in close proximity. Unless the MCC is located in sight of, and within 25 feet of a motor it controls, a disconnect switch shall be provided at that motor. The mechanical engineer shall be responsible for specifying proper types and sizes of motors and controllers and for indicating their locations on drawings. This information must be given to the electrical engineer who shall be responsible for providing suitable feeder sizes, switchgear and transformer capacities, etc. to service motors, and for selecting line voltages and other current characteristics in cooperation with the mechanical engineer.

6.6.5 **Panelboards.**

a. **Types.** Distribution panelboards shall be equipped with automatic circuit breakers of the quick-make quick-break type. Lighting and appliance branch circuit panelboards shall be equipped with automatic time delay circuit breakers.

b. **Distribution Panelboards.** A main distribution panelboard shall be provided with a system that requires secondary service rated 200 to 600 amperes. The main panelboard shall have an overcurrent protective device for each lighting and appliance panelboard. A main distribution panelboard will not be required in a building having either two or three lighting and appliance panelboards and a service disconnecting device with a rating of 200 amperes or less. Branch circuit overcurrent protective devices in a distribution panelboard shall have a trip rating not lower than the calculated load of the feeder served but not exceeding 800 amperes. Each distribution panelboard shall be provided with a number of spare overcurrent protective devices with appropriate ratings and space for anticipated load growth.

c. **Branch Circuit Panelboards.** The requirements below shall apply to lighting and appliance branch circuit panelboards.

1) Panelboards shall be arranged so that each shall contain from 30 to 42 branch circuits, including spares and spaces. The number of spare overcurrent devices and spaces for future overcurrent devices shall not be less than 10 percent of the active circuits. Overcurrent devices shall have 20-ampere ratings, except where higher ratings are required. Overcurrent devices for No. 14 AWG conductors in existing construction shall have a 15-ampere rating. Devices for motor circuits shall have the highest ratings permitted by the NEC for the associated motors and starters. Plug-in breakers are not acceptable.

2) **Emergency Panelboards.** Emergency panelboards shall be provided to supply, through independent circuits, exit lights, stairway lights, emergency lights, building controls, fire pumps, fire alarm and other fire protective systems, and critical research equipment. Emergency panelboards (distribution and branch circuit) shall be fed from one of the sources described in Part 9.

6.6.6 **Electrical Closets.** Except as indicated in i below, electrical closets shall enclose panelboards, feeder conduits, busways, and dry type transformers.

a. **Spacing.** Electrical closets shall be spaced so that 277-volt circuits will not exceed 200 feet in length and so that 120-volt circuits will not exceed 100 feet in length. Latter spacing shall be provided where both 277-volt and 120-volt circuits are fed from the same closet. The above spacing shall be modified to suit underfloor raceway requirements and to suit telephone closet requirements, as necessary, where electrical and telephone closets adjoin.

b. **Location.** Electrical closet locations shall be determined early in the design of a building and shown on design development submission drawings. Closets shall be arranged vertically, one above the other, and shall be accessible from corridors or public spaces. In no case shall access be through another wire closet or from a toilet, toilet vestibule, stairway, or stairway landing. Closets shall not be located where entry of conduits or underfloor raceways is blocked by obstructions such as columns, shear walls, toilets, stairways, flues, janitor gear rooms, service closets, mechanical equipment spaces, vaults, elevator hoistways, and pipe and duct shafts. Where electrical and telephone closets adjoin, the telephone closet should have the position more accessible to the underfloor raceway header capacity. Adjacent electrical and telephone closets shall be provided with a 2-inch sleeve for interconnections.

c. **Size.** Closet shall be ample enough to contain equipment and terminations in initial installation and to allow anticipated future expansion.

d. **Arrangement.** Equipment in each electrical closet shall be arranged for maximum accessibility. To minimize sound transmission, dry tape transformers shall be mounted preferably on the wall or hung from the ceiling to afford maximum working floor space. Contract drawings shall include detail drawings showing the arrangement of equipment, busways, risers, sleeves, transformers, panelboards, tap boxes, junction boxes, cable anchor boxes, wire troughs, and other electrical items to be installed in closets. Where busways pass through closet floors, concrete curbs about three inches high shall be provided around openings. Vertical joints between curbs and walls shall be caulked.

e. **Future Additions.** When it is known that a building is designed for future expansion, sleeves shall be provided in electrical closets for all feeders, communication system conduits, etc. required to serve the future load.

f. **Ventilation.** Ventilation shall be provided, as required, to prevent temperature from exceeding 100° F.

g. **Lighting.** See Part 10.

h. **Receptacles.** A duplex receptacle shall be provided in each electrical closet. Receptacles shall be installed in the wall 12 inches above the floor and connected to a separate 120-volt circuit in a branch circuit panelboard.

i. **Fireproofing.** Where sprayed-on fireproofing is used on the underside of cellular steel floors over electrical closets, suspended ceilings or other means shall be used to cover fireproofing.

j. **Closets Not Required.** Electrical closets may not be required in certain buildings.

Panelboards may be mounted on walls and columns. Wall-mounted panelboards shall be recessed. Access to panel for future circuiting and dry tape transformers, if required, may be installed above accessible ceiling spaces.

PART 7. UNDERGROUND DISTRIBUTION SYSTEM

6.7.1 **Direct Burial.** Install direct burial cables in areas that are rarely disturbed. Restrict direct burial to light loads and to street lighting systems. For protection against mechanical injury, high-voltage direct burial cables shall be provided with a protective covering of steel armor. When corrosion considerations are of importance, armored cables shall be provided with a plastic or synthetic rubber jacket.

6.7.2 **Duct Lines.**

a. **Routes.** Select duct routes to balance maximum flexibility with minimum cost and avoidance of foundations for future buildings and other structures.

b. **Multipurpose conditions.** When it is necessary to combine communication lines with power distribution lines, provide two isolated systems in separate manhole compartments. Where possible, run ducts in same concrete envelope.

c. **Clearance.** Electrical ducts shall be kept clear of other underground utilities, especially high-temperature water or steam pipes.

d. **Materials.** Acceptable standard materials include fiber, clay, plastic, and soapstone.

e. **Size of Ducts.** When sizing conduits, consider the following:

1) For general distribution, standard design requires ducts of 4 or 5 inches.

2) For communication duct banks, a minimum size of 3 inches may be acceptable.

f. **Arrangement of Duct Banks.** For the best configuration, use an arrangement two conduits wide. This arrangement requires only a narrow trench, provides good heat dissipation, and enables cables to be more easily stacked on the manhole walls.

g. **Minimum Coverage.** Top of duct banks shall be kept to a minimum of 18 inches below grade. Under roadways and runways, a minimum coverage of 24 inches is required, and under railway tracks, 36 inches.

h. **Drainage.** Drain ducts to manholes with a constant slope of 3 inches or more per 100 feet. Where two manholes are at different elevations, a single slope following the general slope of the terrain may be the most economical. When grades are flat or crest between manholes, a single slope requires too much depth in one of the manholes.

i. **Spare Capacity.** New underground systems shall include sufficient ducts for planned future expansion.

6.7.3 Manholes and Handholes. Two-section manholes shall be used where power and communication lines follow the same route.

a. **Selection.** Factors bearing on the choice of manholes and handholes include: number, direction, and location of duct runs; cable racking arrangement; method of drainage; adequacy of work space (especially if equipment is to be installed in the manhole); and size of the opening required to install and remove equipment.

b. **Location.** Place manholes or handholes: 1) as required for connection or splices; 2) at street intersections, and 3) where necessary to avoid conflict with other utilities. Manhole separation shall not exceed 600 feet on straight pulls and 300 feet on curved duct runs. Decrease spacing where necessary to prevent installation damage.

c. **Stubs.** Where an extension is anticipated, provide a set of stubs so that the manhole wall will not be disturbed when an extension is made.

6.7.4 Underground Cables. Cable costs make up a large portion of initial investment and future maintenance operating costs, and system reliability. These costs are important in selecting underground cables and accompanying protective and operation devices.

6.7.5 Underground Transformers. Use vaults to house transformers and associated equipment for underground distribution systems.

a. **Vault Design.** Shall include the following provisions:

1) Adequate ventilation shall be provided to prevent a transformer temperature in excess of the values prescribed in ANSI C57.12.00. This limitation requires that most electric heat losses must be removed by ventilation; only a minor part can be dissipated by vault walls. The NEC NFPA No. 70 recommends 3 square inches of clear grating area per kilovolt-ampere of transformer capacity. In localities with above average temperatures, tropical or subtropical, this area should be increased or supplemented by forced ventilation, dependent upon temperature extremes.

2) Adequate access shall be provided for repairs, maintenance, installation, and removal of equipment.

3) Isolation shall be provided to prevent communication of fires of explosions to adjacent vaults.

4) Vaults shall be provided with drainage. When normal drainage is not possible, provide a sump pit to permit the use of a portable pump.

6.7.6 Safety Considerations. Electrical equipment and hardware installed in vaults and manholes shall be effectively grounded to rods provided for this purpose. Metallic sheaths and exterior shields of cables shall be grounded at each manhole.

PART 8. BRANCH CIRCUIT WORK

6.8.1 Wiring and Capacities. Branch circuits shall be provided with insulated copper conductors (minimum No. 12 AWG) in metallic raceways or in cables protected by a metal enclosure. All branch circuits shall have a separate green insulated grounding conductor installed in a raceway along with supply and/or neutral conductors. Non-metallic cable (type NMC, trade name "Romex") or armored cable (type AC, trade name "BX") shall also have a separate insulated or bare copper grounding conductor installed in the cable with the supply and/or neutral conductors. Wiring shall be run concealed. No more than eight duplex receptacles shall be connected to an individual 20-ampere circuit. Individual lighting and appliance branch circuit loads shall not exceed 1600 watts for 120-volt circuits and 3200 watts for 277-volt circuits. Motor branch circuits and special receptacle circuits shall be sized in accordance with the NEC requirements. The branch circuit distribution system type shall be selected based upon a life-cycle cost analysis of at least two competitive systems such as flexible wiring (plug-in) flat conductor cable versus a conventional system (wire and conduit). Flat conductor cable is unacceptable in the research laboratory and associated buildings and facilities. This cable is allowable and more suitable in the administrative and office areas.

6.8.2 Receptacles. In addition to receptacles required for spaces and equipment described above, receptacles shall be provided in the locations for purposes indicated below. A duplex receptacle, referred to below, is a 15-ampere, 125-volt grounding type unless otherwise noted. Furnish grounding conductor for metallic boxes. Connect grounding conductor to receptacle ground terminal, branch circuit grounding conductor(s), and box grounding conductors with a metallic crimp. Wire nuts are not acceptable. Receptacle circuits shall be entirely separate from lighting circuits. Concerning receptacle requirements for the physically handicapped, see OSHA requirements.

a. Provide 15-ampere, 125-volt grounded type weatherproof duplex receptacles near air-conditioning or heating equipment.

b. Provide ground fault interrupter (GFI) protection for each of the following receptacles in addition to those receptacles required to have GFI protection for residential occupancies listed in the NEC: receptacles, 125VAC, 15-, 20-, and 30-ampere, within a 3-foot radius of water supply, such as a sink. Ground fault reset shall be located at the receptacle and not at the panelboard.

6.8.3 Emergency Lighting.

a. **Exit Lights.** Exit lights shall be provided as required by the NFPA, including requirements detailed in the NEC, Life Safety Code, and local codes, and shall be supplied from emergency panelboards.

b. **Emergency Lights.** Emergency lights for egress, including exit routes, exit stairways, exit passageways, large open areas such as assembly areas, cafeterias, and open-plan office spaces where the exit is normally through the major portion of these areas, shall be provided. Mechanical/electrical equipment rooms and vaults, emergency generator rooms, elevator machine rooms and pits, guard rooms, etc. shall also be provided with emergency lights with a minimum

if one foot candle illumination. Emergency lights shall be supplied from emergency panelboards without switch control. Emergency lighting shall be rapid starting; fluorescent lamps or tubes shall light from cold start within 5 seconds.

PART 9. EMERGENCY POWER

6.9.1 **General.** Keep requirements for emergency power to an absolute minimum. Location will provide detailed data describing their minimum emergency power needs, equipment heat generation, and equipment requiring uninterruptible precise power.

6.9.2 **Applications.** Provide emergency power for the following:

a. Elevators which require the use of generators.

b. Critical load requirements; e.g., research and storage of research activities.

c. Equipment that must operate without interruption; e.g., laboratory equipment.

d. Loads to keep buildings with frequent electrical outages operational.

e. Pumps, sewage ejectors, or heating plants requiring power in case of interruption of normal power.

f. Fire protection or other safety equipment requiring power in case of interruption of normal power.

g. Emergency power shall be provided in high-rise buildings where gearless machines are installed.

6.9.3 **Emergency Power Sources.**

a. Batteries and static inverters shall be considered when load does not exceed 20 kVA, provided elevators are not served by them.

b. A single generator shall be provided in each building; where feasible, use a single generating plant for multiple buildings in a complex.

c. Connection to two separate primary sources via appropriate transformers or utility network system may be used in lieu of a generator.

d. Building size and emergency loads and life-cycle costs shall be used to determine if a battery or generator system, or a combination of them, is the most economical emergency power source.

6.9.4 Loads.

a. If elevators require emergency power, load shall depend on the number of elevators as follows:

1) Six elevators or less, the load of one elevator. (Note: Provide feeder connections and other facilities to operate one elevator continuously, while remaining elevators are operated one at a time.)

2) More than six elevators, the load of two elevators. (Note: Provide connections to operate one elevator at a time.)

b. Equipment load shall consist of power required for equipment that must operate continuously, plus that of emergency lights not included in emergency system load.

c. Emergency system load shall consist of lights and equipment served by emergency panelboards.

1) Fire alarm system, fire pumps, security alarm systems, etc.

2) Stairway and escalator lighting.

3) Corridor lighting.

4) Exit and emergency lights in essential machine rooms and guard offices, etc.

5) Emergency receptacles in telephone equipment closets.

6) Equipment, such as communication systems and automatic data processing systems, where an interruption might cause a hazard or other serious problems.

7) Pumps to prevent flooding that might damage buildings or contents, and other essential pumps.

8) Essential heating equipment in cold climates.

9) Emergency loads for generator auxiliary equipment, including:

   a) Damper motors, supply and exhaust fans, radiator fan (remotely mounted radiator only), and generator room ventilation and controls.

   b) Fuel oil transfer pumps.

   c) Battery chargers.

   d) Generator alarms.

   e) Additional motors not driven by the generator engine.

10) Mechanical HVAC control systems.

6.9.5 Uninterruptible Power Requirements.

a. Certain Agency equipment cannot tolerate a short break or minor variation (voltage, frequency, or wave form) in the power supply. Special equipment necessary for uninterruptible power shall be provided.

b. Where a generator is provided, it shall supply emergency power to the uninterruptible power system.

6.9.6 Generators.

a. **System Capacity.** Emergency generator capacity shall be adequate to serve the connected emergency loads. Inrush current of the largest group of motors, automatically started simultaneously, shall be considered. The initial voltage dip shall not exceed 20 percent.

b. **Regenerative load.** Provision shall be made for absorbing regenerative output of lightly loaded ascending elevators and heavily loaded descending elevators. This may be done by increasing emergency lighting load so that it equals the regenerative energy to the elevator load (either one or two elevators). A lighting load arranged to provide for absorbing regenerated energy must function to automatically connect to the generator feeder and be interlocked to prevent energizing the elevator feeder until lighting load is switched on. The lighting load shall also be used as part of the generator exercising load.

c. Where an emergency generator must be automatically started and loaded, the oil supply for the prime mover shall be kept to at least 75 percent of its optimum operating temperature, and a separate electric pump shall maintain a positive continuous flow of lubricant to all bearings.

d. **Load Shedding or Co-generation.** Life-cycle cost analysis shall be performed when a generator is required by other criteria. A cost analysis shall be performed at the tentative or preliminary submission stage, elaborating on the advantages of providing a generator specified to provide continuous, rather than intermittent, operation.

e. **Prime Movers.** Diesel engines shall be used to drive emergency generators. Where gas is available, gas turbines may be used. Prime movers shall not be solely dependent upon a public utility gas system for the fuel supply or municipal water supply for their cooling systems. Provide means

for automatically transferring from one fuel supply to another where dual fuel supplies are used.

f. **Fuel.** The use of diesel oil, No. 2 fuel oil, gasoline, noninterruptible gas, and manufactured gas may be considered after careful evaluation of the reliability of the fuel sources. Other than on-site fuels may be used where there is a low probability of a simultaneous failure of both the off-site fuel delivery system and power from the outside electrical utility company..

g. **Equipment Room.**

1) Equipment shall be installed in a separate room with at least one exterior wall. Where elevators constitute the principal load, equipment should be located near the elevator machine room. The room shall be provided with a fire-resistive enclosure.

2) Noise and vibration and their effect on surrounding rooms shall be considered in selecting the location. Walls of generator rooms shall be constructed of materials to prevent transmission of objectionable levels of sound and vibration.

3) Equipment room shall be provided with adequate ventilation and a combustion air supply. A motor-operated louver damper shall be provided on engine radiator air discharge. Air shall be so discharged that it will not reenter the room.

4) The room shall be provided with adequate access for servicing or replacing equipment.

5) Means shall be provided to heat equipment room to 60^{o} F during idle periods, unless generator is equipped with crankcase heaters for cold starting.

6) There shall be a minimum of three-feet clearance around the generator unit, with greater space provided for large machines.

7) Silencers and major piping shall not be installed above engine-driven generators.

8) Lifting eyes or chainhoist monorails shall be provided over separate components exceeding 50 pounds in weight. Headroom shall be provided to operate lifting devices.

h. **Engine Water Cooling System.** The system, either remote or engine-mounted, shall be so arranged that pressure on the head of the engine block will not exceed 6 psig. Where remote-mounted radiators create static pressure in excess of 6 psig, provide a separate pump, receiver tank and piping to the radiator to prevent rupturing each gasket by excessive pressure. Because of equipment interference, expansion joints, piping, etc., remote radiator design shall be avoided. If engine-mounted radiator is installed in new buildings, cooling systems shall be mounted. Ebullient

cooling shall be considered. City water cooling is discouraged. Where an engine-mounted or remote radiator cannot be used, a cooling connection to a cooling tower must be designed in coordination with the mechanical engineer.

i. **Generator Fuel and Storage.**

1) **Fuel.** Refer to f above.

2) The storage tank shall have fuel capacity for a minimum of five days continuous generator(s) operation at full load. However, larger capacity shall be justified,

depending on the record of electric outages and fuel availability. A separate tank will not be required where a heating fuel tank is available; however, a separate fuel line shall be provided.

3) Day tank, if used, shall provide at least 4 hours continuous generator(s) operation at full load.

j. **Engine Exhaust.**

1) The engine exhaust pipe shall be extended to the exterior of the building as directly as possible, to prevent exhaust discharge from polluting the building.

2) The exhaust system shall be designed in such a manner that the back pressure to the engine will, in no case, exceed 20 inches water gauge.

3) Engine exhaust mufflers (silencers) shall be provided for each engine-generator set to ensure acceptable noise levels.

k. **Generator "Exercising".** Means shall be provided for testing generators with a load equal to at least 50 percent of full rated load. If it is not considered essential or economically justified, automatic test switches and resistor load banks shall not be used; manual switching and the building load shall be used where feasible. Where a separate resistor bank is to be employed for supplementary loading, location of the bank shall be shown on the drawings, and provision made for removing the heat generated.

l. **Paralleling.** Parallel operation of several generators should be avoided if it is possible to divide the load equally among the generators. Where parallel operation is required, auxiliary equipment for automatic operation shall be provided.

6.9.7 Total Energy Systems. The possibility of having a total energy system, where an engine generator or group of engine generators supplies either all or part of the electric power, heating, hot water, and air-conditioning needs for a building, shall be considered. In

conjunction with the mechanical engineer, evaluate the feasibility of such a system to meet prescribed energy consumption goals, for new buildings.

PART 10. ILLUMINATION

6.10.1 Scope. This part outlines the requirements for illumination of ARS buildings, but is not intended to cover all conditions. Where there are unusual problems or conditions, special studies shall be necessary to establish what will be appropriate and economical to install, maintain, and operate.

6.10.2 Lighting Systems. Lighting systems shall be designed with fluorescent lighting fixtures and lighting equipment utilizing energy saving rapid-start, cool-white or warm-white lamps. Ballasts shall be energy efficient, and shall meet UL Class P requirements, equipped with built-in automatic reset thermal protector. Ballasts shall have a sound rating.

6.10.3 Design Considerations.

a. **Architectural Requirements.** Lighting systems shall be coordinated with building design of aesthetic and decorative effects within the limits of visibility, visual comfort, economics and energy conservation.

b. **Design Analysis.** Lighting calculations shall adhere to the established procedures of the IES Lighting Handbook and IES recommended practices.

1) **Standard Illumination Analyses.** For general applications, average illumination may be calculated using room cavity ratios and luminaire coefficients of utilization (zonal-cavity method).

2) **Special Computer Analyses.** Where comprehensive lighting studies are required to determine alternative lighting sources for large multi-roomed buildings or average-to- minimum illumination (point-by-point method), it may be necessary to perform a computer analysis to be submitted during the preliminary design stage.

c. **Calculations.** Calculations shall adhere to established procedures of the IES Lighting Handbook; zonal-cavity method shall be used; this shall be accomplished by computer.

d. **Economics.** For large buildings, a comprehensive lighting study shall be required from an economic viewpoint to aid the selection. When studying alternatives, consider initial investment, life span of the installation, energy expense, cost of replacing lamps, and cleaning cost.

e. **Energy Conservation.** The following methods shall be considered:

1) Switching flexibility.

2) Time or photoelectric control.

3) Use of high efficiency lighting fixtures and systems.

4) Provision of ceiling construction and wiring methods which easily accommodate luminaire relocation.

5) Use of building automation systems for switching lights.

6.10.4 Luminaires. Particular effort shall be made to reduce the number of luminaire types in any one facility, building, or project, so that the number of spare part replacements required for maintenance shall be kept to an absolute minimum.

6.10.5 Maintenance. Ease of servicing luminaires must be considered in the design process. For lighting fixtures installed in areas where it is difficult and hazardous to relamp fixtures when using ladders (e.g., ceiling fixtures in stairwells), consider use of open bottom fixture enclosures that provide access for reamping with a lamp changer.

6.10.6 Switches.

a. Local light switch control shall be provided for individual rooms with fixed partitions. Four-lamp fixtures may be double switched to provide two levels of illumination.

b. Office lighting shall be controlled by switches mounted on permanent partitions and columns (off center line). Switches in relocatable partitions shall be avoided wherever possible. Local switching shall be provided to insure maximum flexibility.

c. Corridor lighting shall be controlled by switched located near the elevator core or by a remote control system.

d. If a building automation system (BAS) is available, it shall be used for switching of lights.

6.10.7 Exterior Lighting.

Parking Areas, Exterior Traffic Lanes, and Pathways to Buildings. These areas shall be illuminated with luminaires designed for use with high-pressure sodium lamps providing illumination levels shown in IES standards.

PART 11. SPECIAL EQUIPMENT

6.11.1 Computer Room Installations.

a. **Location.** Computer rooms shall be located in expandable interior areas to avoid condensation and sun load problems.

b. **Electrical loads.**

1) **Lighting.** Fluorescent 50 foot-candles not exceeding 1.4 watts per square foot.

2) **Computer Equipment.** Approximately 30 to 40 watts per square foot.

3) **Air-Conditioning.** Approximately 15 to 20 watts per square foot based an floor-mounted packaged units.

4) **Future Expansion.** Allow 25 percent spare capacity for feeders and panelboards.

c. **Feeders.** Each computer area shall be provided with an independent feeder to serve anticipated equipment loads. An independent feeder shall also be provided to serve the air-conditioning system. Each feeder shall have a minimum of two sources and an automatic transfer means or a single source initially with provision for adding a second source. The sources may be two different spot network substations in large buildings or normal power and emergency engine-generator unit, depending on the criticality of the computer operation, type of computer equipment, reliability of the normal power source, and availability of funds.

d. **Panelboards.** Computer and air-conditioning feeders shall terminate in special panelboards within the area. Panelboards shall be provided with remote control switches, etc. to permit disconnecting computer and air-conditioning equipment by master switches described in e, below.

e. **Local Power Manual Shutdown.** A manual master switch shall be provided at each entrance to the computer area to disconnect power to computer and air-conditioning equipment, but not lighting. Each switch shall be enclosed behind a breakglass panel which shall be clearly labeled and provided with key opening for test purposes.

f. **Wire Under Raised Floors.** Consider the following factors and requirements:

1) Temperature: With air-conditioning down to 55º F.

2) Humidity: Up to 95 percent.

3) Current rating of branch circuit conductors: Minimum 125 percent of connected load.

4) Raceways: Extend conduit (magnetic shielding) to weatherproof junction boxes or receptacles. Route conduit clear of, or under, air-conditioning ducts.

5) Avoid use of PVC because dense smoke is produced when it is burned. Also, PVC forms hydrochloric acid (HC1) when combined with water, which may seep into structural concrete and attack reinforcing rods and other structural steel.

g. **Wiring Without Raised Floor.** Consider floor boxes or underfloor duct for power and controls.

h. **Fire Protection.** Smoke detection, sprinkler system, or Halon fire extinguishing system shall be installed in accordance with National Fire Codes.

i. **Grounding.**

1) Include full size ground conductor with feeder from switchboard and with each branch circuit from computer room panelboard.

2) Ground at least one raised floor support pedestal.

3) Check ground continuity of metallic raised floor elements.

4) Check HVAC air outlets in floor. If metallic, provide ground jumpers to continuous metallic grounded flooring or panel ground bus.

6.11.2 Elevators.

a. **Feeders.** Each isolated elevator and each group of two elevators shall be provided with an individual feeder. Each group of three or more elevators shall be provided with not less than two feeders. Where feasible, feeders serving a group of four or more elevators should originate in different substations.

b. **Switchboards.** Switchgear assembly, generally a NEMA Type I, shall be provided where there are two feeders as described in subparagraph a., above. The bus shall be divided so that each feeder connects to a separate section serving half of the load. For each elevator served, the switchgear assembly shall be provided with a circuit breaker. In addition, provide an automatic transfer switch and feed to panelboard for signal power, etc., as described in d., below. A transformer shall also be provided, where necessary, to furnish the required voltage.

c. **Circuit Breakers.** Each elevator feeder shall terminate in a separately enclosed wall-mounted circuit breaker.

d. **Signal Power.** A panelboard fed by the transfer switch described in b., above, shall be provided for elevators. The panelboard shall contain circuit breakers to supply power for either signals or group supervisory control car light. Where freight elevators are equipped with freight type power-operated hoistway doors, a 3-pole circuit breaker of suitable size shall be provided to supply power for the doors.

e. **Wiring.** Wiring shall be provided to the terminals of controls furnished by the elevator contractor. Where controls are not in the same rooms as switchgear assemblies with circuit breakers required above, additional disconnect switches shall be provided per NEC requirements.

f. **Receptacles.** Not less than one duplex receptacle shall be provided on each elevator machine room wall. A duplex weatherproof receptacle and light fixture shall also be provided in each individual elevator pit and in each section of a multiple-hoistway pit.

g. **Emergency Power for Elevators.** When emergency power is provided from a standby engine-generator set, automatic transfer switch(es) should be provided, and normal feeder(s) shall be utilized to distribute emergency power. Where use of normal feeder(s) is determined to be impractical for this purpose, emergency feeder(s) and necessary automatic transfer switch(es) shall be provided. Auxiliary control contacts shall be provided on each automatic transfer switch, plus conductors in conduit extending to controls in the elevator machine room. Auxiliary contact circuit, in conjunction with elevator controls, shall function to prevent any elevator from starting automatically as long as emergency power is being applied to elevators. A selector switch shall be provided as part of the elevator installation which will permit authorized personnel to select one (or a limited number of) elevator(s) at a time for operation on emergency power to:

1) Release passengers who may be trapped in a stalled elevator, and

2) Provide limited emergency power to authorized personnel during the power interruption.

h. **Elevator Fire Capture System.** This system shall meet ANSI A17.1 code.

6.11.3 **Hazardous Locations.** Equipment, material, and devices installed in hazardous locations and details of their installation shall conform to NBC requirements and other applicable recommendations of NFPA. Hazardous locations include paint shops, and locations exposed to flammable liquids and gases and combustible dust and fibers, as defined by the NEC Article 500. Requirements of local agencies having jurisdiction over the completed project shall also be met.

6.11.4 **Lightning Protection.** All metal flagpoles and metal stacks either attached to buildings or free standing shall be grounded. All facilities having a lightning risk assessment index (R) greater than or equal to three (3) determined in accordance with NFPA-78-1983 (Lightning Protection Code) shall have complete lightning protection systems included in their design. A complete lightning protection system is a system of air terminals, conductors, ground terminals, interconnecting conductors, arresters, and other connectors or fittings required to complete the system. Facilities having R values less than 3 shall be evaluated by the design A-E in conjunction with the project EPM with respect to safety, research program, and economic factors to determine the extent of lightning protection required.

PART 12. COMMUNICATION AND SIGNALING SYSTEMS

6.12.1 **Telephone Systems.**

a. **General.** Telecommunications distribution facilities shall be integrated early on into the physical construction design plans. The local telephone company (LTC) will install, own, and maintain all cable, wiring, and associated terminating hardware needed to provide access to the public switched network. Construction design elements identified in this section are not provided by the LTC, and include 1) conduit; 2) raceways; 3) equipment space; and 4) other facilities that are part of the building structure itself.

b. **Service Entrance and Local Telephone Terminations.** Telecommunication distribution designs shall fully support LTC facility entrance and termination points within the structure. Additionally, LTC service entrance facilities shall include the provisions as to: 1) the path these facilities follow along governmental property; 2) their entrance point to the building; and 3) their termination point. Discussions with the LTC shall determine, early on, the use of: 1) underground entrances; 2) buried entrances; or 3) aerial entrances. As is the custom of the building owner to provide for the LTC the conduit from the main terminal location or building entrance location to the property line, pole, or manhole, provisions shall be incorporated.

1) **Terminating Conduit Inside a Building.** Design conduits entering from "below grade" point shall extend 4 inches above the finished floor. Design conduits entering from a ceiling height shall terminate 4 inches below the finished ceiling.

2) **Bonding and Grounding.** Bonding and grounding of the telecommunications distribution design shall follow Articles 250 and 800 of the NEC covering general requirements for

grounding, bonding, and protecting electrical and communications circuits.

c. **Terminating Space for Entrance Facilities.** Building space shall be set aside for the termination of entrance facilities and shall provide for: 1) electrically protected; 2) secure; and 3) adequate spacing requirements to meet the building's cable distribution system. Space provided for this purpose therefore shall be: 1) near or at the point where facilities enter the building; 2) be well lighted, providing for a minimum lighting of 30 foot candles, at floor level; 3) environmentally clean; 4) provided multiple 15 amp duplex-grounded outlet for testing and maintenance; 5) equipped with 3/4-inch fire retardant plywood, securely fastened to supporting walls; and 6) provided access to an approved grounding connection.

d. **Equipment Room.** Equipment rooms shall be considered distinct from the building entrance facilities insofar as the equipment rooms shall provide for more stringent environmental requirements, and shall house the major components of the building telecommunications system. Three basic system types shall be considered with regard to the building design considerations:
1) central office based services provided by the LTC; 2) key telephone service; and 3) PBX service. Key telephone or PBX services shall be provided with dedicated space to

house equipment. Additionally, the larger and more complex the system, the more space shall be made available.

1) **Environmental Considerations.** Environmental requirements shall consider telephone switching system requirements to include 1) operating temperatures ranging from 32 to 100 degrees F; 2) humidity ranging from 0 to 55 percent, relative, and 3) heat dissipation ranges from 750 BTUs per hour to 5000 BTUs per hour per cabinet.

2) **Battery Requirements.** Consideration shall be given for UPS requirements, as necessary. Battery floor loading requirements shall vary, depending upon the occupants requirements, and can be as low as 100 pounds per square foot to as high as 600 pounds per square foot. PBX UPS shall be governed by NEC, Articles 480 and 503-14, dealing with code requirements for storage batteries and their associated charging equipment. (Local codes may place more rigorous requirements on storage battery installations.)

3) **Lighting Requirements.** Lighting fixtures shall not be placed where they will be above 1) the equipment cabinets; 2) the termination frames; or 3) other free standing equipment. Equipment space shall have lighting that provides a uniform light intensity of 30 LM/Ft2 when taken at floor level.

4) **Electrical Requirements.** Manufacturer specifications shall guide the basic telephone system(s) electrical requirement. Additionally, PBX installations shall require specialized bonding and grounding of equipment cabinets.

5) **Distribution Cable Termination Requirements.** Space requirements for distribution cable shall allow for wall mounted terminal fields, free standing frames, or both. For wall mounted terminal field applications, a 3-foot clear work space shall be provided across the entire field.

6) **Structural Requirements.** Walls of the equipment rooms shall extend from the finished floor to ceiling height and be finished by painting with a minimum two coats of fire retardant paint. Equipment room flooring shall be finished to keep dust to a minimum. Equipment room floor loading requirements shall support equipment cabinets between 50 pounds per square foot to 200 pounds per square foot. Additionally, a minimum ceiling height of 8 feet, 6 inches shall be provided to allow for the adequate clearance of equipment frames for cables and suspended racks.

e. **Telephone Closets.** Three types of floor closet shall be considered in design specifications. Types shall vary as to the 1) size of the building; 2) number of floors; 3) occupancy characteristics; and 4) telecommunications services to be used. Doorways shall be designed with a minimum measurement of 3 feet wide by 6 feet, 8 inches high--measurements shall be exclusive of a doorsill or center post. Doors shall be hinged to either open outward, slide side-to-side, or be removable. Floor closets shall be: 1) located in areas above the threat of flooding; 2) provided a No. 6 AWG wire from an approved floor ground; and 3) be provided lighting equivalent to a minimum of 30 foot candles measured at floor level. Closets may vary in size depending on their function; however, no closet shall be less than 12 inches deep. All closets shall be 1) lined with a minimum of 3/8 inch thick 8 feet (height) plywood, fastened to the wall framing members; 2) have the plywood painted with fire-resistant paint; and 3) whenever possible, be located on wall space for termination on one continuous wall.

1) **Riser Closets.** Riser closets shall be used in low, wide buildings where the riser cable is run horizontally, or to provide distribution points on each floor of a multistory building. Riser sleeves/slots shall 1) be provided with a minimum 4-inch diameter; 2) be located on the immediate left side of the closet; 3) be provided 110 VAC duplex power outlets; 4) be fitted with a sufficient number of risers sleeves to accommodate the anticipated needs of the occupant; and 5) be provided lighting equivalent to a minimum of 30 foot candles measured at floor level.

2) **Apparatus Closets.** Apparatus closets shall provide cross-connect fields for station cables and tie cables to satellite closets, or to house key system controllers and other common equipment that requires commercial AC power.

Apparatus closets shall be constructed with a minimum depth of 24 inches, and provide for a minimum of one 110 VAC duplex power outlet which is both separately fused and provides a 20 amp, 3-wire, grounded outlet. (Riser and apparatus closets may be combined.)

3) **Satellite Closets.** Satellite closets shall provide solely supplemental distribution points for station cables, and shall not provide for key equipment or riser cable distribution. Satellite closets shall be provided with a minimum depth of 12 inches, and a minimum recommended sizing of 2 feet, 4 inches wide.

f. **Conduits.** A complete conduit system shall be indicated on the drawings, with routing of main conduits, sizes and locations of pull boxes, and method of termination shown. Minimum conduit size for telephone outlets shall be 1 inch, except that 3/4-inch conduit may be used in buildings having less than 10,000 net square feet of general office space, and for public telephones, telephones in kitchens, snack bars, shops, elevator machine rooms, and electrical or mechanical equipment spaces of similar character. Special isolation and sealing of main panels, conduits, and main distribution lines are required in contained laboratory and animal space. See Chapters 9, 10, and 11.

g. **Telephone Rooms**

Telephone Rooms shall be considered in design specifications. Room size shall vary as to 1) size of building, 2) number of floors, 3) occupancy characteristics; and 4) telecommunication services to be used. Telephone equipment rooms are considered to be distinct from telecommunications closets because of the nature or complexity of the equipment they contain. Any or all of the functions of a telecommunication closet may be alternatively provided by a telephone equipment room.
Design of a telephone equipment room shall be in accordance with the requirements of the Electronics Industry Association (EIA) and Telecommunications Industry Association (TIA) specification EIA/TIA-569.

Telephone rooms may be immediately adjacent to or combined with space identified for LTC service entrance and/or terminating facilities.

Referenced standards (EIA/TIA-569) identify minimum requirements for square-footage, lighting, atmospheric controls and AC power based upon type and quantity of equipment to be installed.

6.12.2 Fire Alarm Systems.

a. **Location of Control Console.** The control console shall be installed in the engineer's office, and a remote graphic annunciator shall be installed in the lobby within view of, and easily accessible to, outside fire fighting personnel. In buildings where 24-hour guard service is provided, the control console may be located in the guard's office with remote indicator in the engineer's office.

b. **General Alarm Bells.** Where bells are used, they shall be located so that they can be heard in every room. Where partitions prevent distribution of sound, additional bells shall be provided. An alarm bell shall be located above each fire alarm station and at such locations as may be required to assure full coverage.

c. **Power Supply.** Power to supply fire alarm systems shall be taken from the building service on the supply side of the main service switch. Where the building is supplied by primary service, the fire alarm power supply shall be taken from the emergency lighting panelboard.

6.12.3 **Public Address Systems.** Conduit systems to accommodate the public address system equipment shall be provided in each auditorium.

CHAPTER 7. SAFETY AND HEALTH ELEMENTSTS
PART 1. GENERAL

7.1.1 **Purpose and Objective.** A safe and healthy work environment is the crucial objective in the design of Agency facilities. The requirements listed in this section are the minimum Agency requirements to meet this objective. Unless specific reference is made otherwise, all codes and standards cited in this chapter shall be the latest edition. Both NFPA Life Safety Codes and model building codes permit equivalency concepts. All deviations from this document and any equivalency concepts proposed for use, must be identified by the A-E and submitted to the Engineering Project Manager (EPM) for approval no later than the 35 percent design stage. The request must state the deviation/equivalency concept proposed, reasons for the request, and supporting rationale. The EPM will coordinate the request with the appropriate office and provide a response to the A-E.

7.1.2 **Definition of Laboratory.** A laboratory is defined as a building space, room or operation used for testing, analysis, research, instruction, or similar activities. An area, exclusive of maintenance shops, is considered a laboratory if any of the following exist: (Refer to Chapter 9 for Biohazard Containment Design.)

a. Fume hood/biosafety cabinets or other primary barriers.

b. Incidental use or storage of chemicals with any of the following properties:

1) Flammable
2) Combustible
3) Explosive
4) Water Sensitive
5) Caustic
6) Corrosive
7) High or unknown toxicity
8) Carcinogen

c. Biohazardous material.

d. Grinding operations (excluding metal).

e. Radioactive material/ionizing radiation emanating equipment.

7.1.3 **Codes and Special Requirements**. Requirements relating to safety and health in the Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA) regulations, American Conference of Governmental Industrial Hygienists Industrial Ventilation Manual, henceforth referred to as ACGIH, Standards of the American Society of Heating, Air- Conditioning Engineers, Inc. (ASHRAE), Agricultural Research Service (ARS) safety and health policy, and local building and fire codes must be met as a minimum to achieve a safe and healthy work environment. Where a conflict arises, the most stringent requirement shall govern. (Refer to Chapter 9 for Biohazard Containment Design.)

a. **Department of Labor Standards**. The project shall be designed to comply with the latest versions of the applicable OSHA Standards (2) CFR Part 1910) and Safety and Health Regulations for Construction (29 CFR Part 1926) as promulgated by the Department of Labor.

b. **National Fire Protection Association Codes**. The project shall be designed to comply with the most current edition of the National Fire Code, as promulgated by the NFPA.

c. **U. S. Department of Health and Human Services Biosafety Guidelines**. The project design shall be in compliance with the latest revision of the applicable Biosafety Guidelines (promulgated by the Centers for Disease Control, and National Institutes of Health, NIH) applicable to the level and nature of the project research activities. (Specific guidance for biohazard containment design can be found in Chapter 9.)

d. **USDA, Radiological Safety Staff**. The project shall be designed to comply with the latest Nuclear Regulatory Commission regulations (contained in 10 CFR 20), ACGIH, and license conditions where appropriate.

e. **Laboratory Chemical Fume Hoods Standards**. The project shall be designed to comply with the latest revision of the ACGIH, as well as specific requirements of this section.

f. **American National Standards Institute**. The drawings and specifications for each project shall show and require safety and health construction features and practices which conform to the most current ANSI Standards noted in the ANSI Safety and Health Index, Publication SP8L-PC20M1085.

g. **Model Building Codes**. The project shall be designed in accordance with the prevailing Model Building Codes (BOCA, ICBO, SBCCI) enacted in the project area.

PART 2. ELEMENTS OF DESIGN

7.2.1 **HVAC System**. The HVAC system shall be designed with at least the following minimum requirements: (Where a conflict arises, the most stringent requirement shall govern.)

a. Separate HVAC systems shall be provided for laboratory areas, animal holding areas, and non laboratory administrative areas.

b. Ventilation requirements for electrical shops, photography laboratories, and other special use areas shall be as prescribed in the applicable Standard of The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE).

c. A minimum of fifteen (15) air changes per hour are required for animal facilities including independent temperature and humidity controls. Recirculation of exhaust air from animal facilities is prohibited. (Refer to Chapter 10 for animal research and care facilities design.)

d. A minimum of eight (8) air changes per hour is required in laboratories and recirculation of exhaust air from laboratories is prohibited.

e. All other areas shall be provided with an adequate level of fresh air (minimum of 20 percent) from the HVAC air intake system. The minimum air changes for office space is six per hour.

7.2.2 **Laboratory Ventilation:** The provisions of NFPA 45, ASHRAE, and ACGIH for ventilation and fume hoods shall be strictly adhered to. Where a conflict arises, the most stringent requirement shall govern. (Refer to Chapter 9 for Biohazard Containment Design.)

a. Except for certain biocontainment applications, the air pressure must be negative relative to the corridors or other common use spaces. Hallways and corridors shall not be used as return air plenums, and louvers will not be permitted in fire rated doors. (Refer to Chapter 9 for Biohazard Containment Design.)

b. All exhaust air shall be ducted. Interstitial space shall not be used as a plenum to exhaust laboratory areas.

c. Recirculation of laboratory air is prohibited.

d. Supply air diffusers shall be placed so as not to interfere with the function of fume hoods. Supply air diffusers and exhaust inlets shall be placed so that the room is swept by the air with short circuits being avoided. (Refer to ASHRAE for additional information.)

7.2.3 Fume Hood Requirements: All laboratory chemical fume hoods and exhaust systems shall comply with ACGIH guidelines as well as the guidelines presented in this section. Surfaces must be durable and easily cleanable. Service outlets shall be located so that the operator will not have to reach into the hazard zone to make connections. Variable Air Volume (VAV) and Bypass hoods shall be used in new construction and renovation. (Refer to Chapter 9 for Biohazard Containment Design.)

a. Face velocities shall be 400-500 mm/s (80-100 fpm).

b. Stack heights shall be determined by the height of the building (building envelope), proximity to other buildings, local topography, prevailing winds, and weather conditions. The minimum stack height shall be 3 m (10 ft.) from the plane of the roof. The absolute minimum exhaust velocity shall be 12.7 m/s (2500 fpm) at the discharge point of the exhaust stack.

Aesthetic objections to high stack heights shall be overcome with architectural treatment. An exhaust tower or a cluster (bundle) of exhaust stacks can be made an element of the building and is an acceptable method of achieving this. The bundling of exhaust stacks has the added advantage of creating a plume of exhausted gases which is less readily deflected from upward vertical flow by wind gusts. A further, although very costly, alternative is to provide for remote intake of inlet supply locations. The use of cone-style weather caps is prohibited.

Exhaust stacks and air intake inlets shall be located at appropriate distances from each other in order to provide proper dilution and recirculation of exhausted air. (See ASHRAE Standard for additional guidance.)

c. Hood locations must be away from doors, windows, and occupant traffic.

d. The laboratory hood manufacturer shall provide certification that the unit performs satisfactorily under the conditions required by the design documents. ACGIH specifications and procedures for certifying aerodynamic performance of installed fume hoods must be clearly defined in the project specifications.

e. Where fume hoods or biosafety cabinets are placed opposite one another, the design shall take into consideration egress and aerodynamic considerations.

7.2.4 Fume Hood Exhaust Requirements.

a. Individual exhaust systems must be provided for each fume hood. Manifolding of up to four hoods may be considered. (See Paragraph 7.1.1 for procedure to document deviation requests.)

b. Fume hoods shall be designed to operate on a 24 hour basis. Night set back of fume hood exhaust systems (reduction in output) may be considered to a minimum of 50 percent of occupied mode volume. Where chemical storage cabinets are power ventilated, the laboratory HVAC system volume of air flow can be reduced, or "set back", during those hours when the laboratory is not occupied.

c. Fans must be installed so that all ducts within the building are maintained under negative pressure.

7.2.5 Radioisotope Fume Hood. All laboratory fume hoods for radioisotope work shall be designed in compliance with ACGIH; all benchtop, sink, and floor material must be durable and easily cleanable (coved corners and joints); all service outlets shall be located so that the operator will not have to reach into the hazardous zone to make connections; and the appropriate filters shall be included.

7.2.6 Perchloric Acid Hoods. Perchloric acid hoods shall meet the criteria identified in NFPA 45 and ACGIH. If perchloric acid hoods are not required in accordance with the POR for current research needs, but could be required in the future, as determined by the Program Project Manager, the A-E shall incorporate into the design package, as a minimum, one rough-in (i.e., ductwork and plumbing hookup).

7.2.7 **Laminar Flow Hoods**. Only vertical laminar flow biological cabinets shall be used in Agency facilities. Horizontal laminar flow cabinets shall not be installed.

7.2.8 **General Purpose Hoods**. Hoods for all other purposes shall be designed in accordance with ACGIH.

7.2.9 **Incinerators** shall meet or exceed all State, local, Environmental Protection Agency and National Fire Code requirements. It is crucial that incinerators for radioactive materials shall meet or exceed Nuclear Regulatory Commission and all applicable codes and/or requirements. (Refer to 40 CFR Part 264 and NFPA 82, and 86.)

7.2.10 **Chemical Storage**.

a. Laboratories which use flammable/combustible materials and chemicals shall provide adequate storage in a segregated, vented storage cabinet in accordance with NFPA 30, Flammable and Combustible Liquids Code and NFPA 45, Fire Protection for Laboratories Using Chemicals.

b. In each laboratory where corrosive materials will be used, there shall be a segregated corrosive material storage cabinet. Use corrosion resistant materials suitable for their intended use.

c. Provisions for storage of carcinogenic chemicals in each laboratory shall be in accordance with the applicable OSHA standards in 29 CFR Part 1910.

d. Compressed gases shall be manifolded at a central location closest to those laboratories they serve. Efforts shall be taken to avoid extraneous use of gas cylinders in laboratories.

e. The design of any area for the express purpose of storage of compressed gases and flammable combustible materials shall comply with OSHA Standards in 29 CFR 1910, Subparagraph H, Hazardous Materials; NFPA 30, Flammable and Combustible Liquids; NFPA 45, Fire Protection for Laboratories Using Chemicals, and Compressed Gas Association, Pamphlet P-1.

7.2.11 Additional Exits

a. Each laboratory shall have an additional means of exit remote from the primary exit. Adjacent laboratories may share this remote exit via a common separation wall. Mechanical equipment rooms, boiler room, and furnace room shall have an additional means of exit, remote from the primary exit.

b. The A-E shall provide, as part of the first submittal, a conceptual layout identifying the means of exit.

7.2.12 Occupancy Classification. Agency structures must be classified in accordance with the established local building codes of the jurisdiction in which the structure is to be located. In addition to local building codes, the Agency has set the following additional requirements for all laboratories as previously defined. The Program of Requirements (POR) developed by the A-E will include a list of all applicable codes and the name and address of the local code authority. (Refer to NFPA 101 Life Safety Code [1991], NFPA 41, and 45, for additional information.

a. Dead-end pockets in hallways corridors, passageways, or courts are discouraged. However, in no case, will any such pocket exceed code allowances.

b. Travel distances for high hazard areas (NFPA 101, 5-11.1) and high hazard laboratories (NFPA 45, 2.2, Table 2.2) will not exceed 23 m (75 ft.). Travel distances from all other laboratories shall not exceed 45 m (150 ft.).

c. All laboratories (paragraph 7.1.2) shall be designed in accordance with NFPA 45. Laboratory exit corridors will not be used as "exits" in order to increase travel distances along exit access route to exit stairs or ramps. Where stair enclosures are part of a design, it is the Agency's policy to make these stair enclosures the primary protected means of egress from a building.

d. As part of the first submittal, the design firm must document coordination with code officials and provide for the Agency's review, a code analysis addressing building classification and requirements.

7.2.13 **Emergency Eye/Face Wash and Shower Station**. Each laboratory, chemical storage room, or chemical handling room, shall have an emergency eye/face wash and shower in accordance with ANSI Z358.1 (latest edition), Emergency Eyewash and Shower Equipment.

a. Wall-mounted portable units and handheld singlehead devices are not acceptable in lieu of stationary dual-head eye washes.

b. Emergency showers shall be Located within 30 m (l00 ft.) or 10 seconds travel time from potential injury source. Showers should be installed closer to the potential injury sources if such sources are highly corrosive chemicals. Emergency shower stations should provide natural screening where possible. The preferred location is inside the laboratory.

c. Eye wash stations may be installed as integral components with laboratory sinks or the emergency showers.

d. Each laboratory shall have a floor drain, collocated with the emergency shower.

7.2.14 **Laboratory Furniture**. Laboratory furniture shall be designed such that:

a. It is corrosion resistant.

b. Contamination removal from surfaces is not difficult.

c. It is arranged so as not to impede egress in an emergency.

d. The working surface is free from cracks and sensible joints.

7.2.15 **Asbestos**. All work involving asbestos-containing materials shall be performed in accordance with OSHA standards contained in 29 CFR Part 1910.1001, as applicable, as well as those Federal and State EPA regulations that pertain to asbestos-containing material maintenance and abatement.

7.2.16 **Fire, Smoke' and Heat Safety**.

a. **Portable Fire Extinguishers**. The appropriate number, types, and locations of fire extinguishers must be provided in accordance with NFPA 10, "Portable Fire extinguishers." Whenever possible, the 10 pound ABC Multipurpose fire extinguisher shall be provided in a recessed cabinet and located in the corridors. Halogenated (1211 or 1301) fire extinguishers will not be used.

b. **Fire, Heat and Smoke Detection Systems**. All corridors, meeting rooms, and storage rooms will be protected by smoke detectors. When required in other areas by code, automatic fire detectors will be installed. If the structure cannot be protected by a fire suppression system, a complete automatic fire detector system is required.

Automatic fire detectors shall be located, mounted, tested, and maintained in accordance with NFPA 72.

c. **Fire suppression systems**. Fire suppression systems shall be designed and installed in accordance with Federal, State, or local codes. It is ARS' policy to install sprinkler systems in all laboratory facilities.

d. **Fire Alarm Systems**. Fire alarm systems shall be installed in accordance with NFPA 72. A manual fire alarm system (at a minimum) will be installed in a structure if a fire may not, of itself, provide adequate warning to building occupants.

e. **Miscellaneous** Standpipes, in accordance with NFPA 14, will be installed in laboratory buildings of two or more stories above or below street level.

HVAC smoke control must be used if mandated by NFPA 90A.

The locating of storage and handling of flammable liquids and gases where it would jeopardize egress from the structure will not be permitted.

7.2.17 **Animal Facilities**. Special consideration shall be given to the design of individual animal rooms. Design must ensure that all research animals are protected to prevent transmission of diseases among animals and to and from humans. (Refer to Chapter 10 for requirements.)

CHAPTER 8. ELEVATORS (VERTICAL TRANSPORTATION SYSTEMS)
PART 1. GENERAL

8.1.1 **Scope.** This chapter deals with design requirements for elevators or vertical transportation systems for Federal buildings.

8.1.2 **Codes.** New elevators or vertical transportation equipment installations shall conform to the American Society of Mechanical Engineers (ASME) Safety Code for Elevators and Escalators, A17.1 (herein referred to as the A17.1 Code). Existing elevators or vertical transportation equipment shall be improved as appropriate to conform to the A17.1 Code.

PART 2. EQUIPMENT

8.2.1 **Passenger Elevators.**

a. **Classification.**

1) Passenger elevators.

2) Combination passenger and freight elevators.

3) Special purpose elevators.

4) Shuttle elevators.

b. **Planning.** Passenger elevators shall be located so that the building entrances with heaviest traffic will have adequate elevator service.

c. **Size and Number.** The following factors shall be considered in determining the size and number of passenger elevators required.

1) **Cost.** The overall annual cost of the elevator facilities, including amortized cost of the original investment, maintenance, material, and consumed power.

2) **Net Area.** This is the floor area of the building served by the elevators

exclusive of the main (street) floor mechanical and electrical rooms, parking areas, cafeterias, stairways, toilets, corridors, and similar areas.

3) **Population Density.** This is the net area per person. Building populations above the main floor shall be estimated an the basis of 135 sq. ft. net area per person.

4) **Maximum Traffic Peak.** This is the maximum percentage of the total population that shall be handled during any five-minute period. In general, the maximum traffic peak shall be considered as being that produced by the morning filling of the building.

5) **Traffic Distribution.** Groups of elevators serving identical floors are required to be furnished at two or more locations to provide reasonable convenience of use; the elevators shall provide a minimum carrying capacity of not less than 120 percent of the maximum traffic peak. This factor provides for the unequal distribution of traffic when elevator groups occur at more than one location. Calculations based on the above factors shall be submitted as part of the design concept submission where two or more passenger elevators are required.

d. **Capacity, Speed, and Interval.**

1) A capacity and speed shall be selected that will require the least number of passenger elevators to handle the peak load with an acceptable time interval of dispatch. The average peak period loading shall be assumed as 80 percent of rated car passenger carrying capacity based on an average passenger weight of 150 pounds. For office buildings, the most suitable car capacities are from 3,000 to 4,000 pounds. In some instances, larger capacities shall be required. Passenger elevators with capacities under 2,500 pounds shall not be installed, as they are not suitable for maneuvering a wheelchair. For local service, there is no appreciable saving in time by the use of car speeds exceeding 500 fpm.

2) For tower office buildings, elevators shall be arranged in a low-rise group, a high-rise group, and possibly intermediate-rise group(s), depending on the height of the building. Each group must include enough elevators to satisfy the requirement for dispatching interval. Speed shall range from 500 fpm to 2,000 fpm.

3) Where there is only one elevator in the public building, it shall have a minimum capacity of 4,000 pounds and shall be classified as a combination passenger and freight elevator.

4) Dispatching intervals are classified as follows: 18 to 23 seconds - excellent; 24 to 29 seconds - good; 30 to 35 seconds - fair; 36 seconds and over - poor. Where there are four or more elevators in a group, the dispatch interval shall be in the excellent or good range. Where there are fewer than four elevators in the group, the interval shall be kept to a practical minimum; however, it is recognized that economics may sometimes require acceptance of an interval classed in the fair or poor range. For single elevators and two-car group elevators, the interval shall be much higher, ranging to over 60 seconds for a single elevator depending on the speed and number of floors served.

e. **Handicapped Considerations.** Passenger elevators shall be designed to accommodate individuals with physical disabilities. For suggested minimum requirement, refer to Uniform Federal Accessibility Standards. Individual markers shall not be accepted. Characters on car operating panels and call button stations shall be cut into faceplate as an integral part of faceplates.

f. **Combination Passenger and Freight Elevators.** If a separate freight elevator is not provided, requirements for freight service shall be considered in determining the number and duty of elevators. A combination passenger and freight elevator must have the size and capacity to accommodate the anticipated demand, and generally shall be not less than 4,000 pounds in capacity, preferably larger when hoistway space is available. Door openings shall be not less than 3 feet, 10 inches wide. Combination passenger and freight elevators are not recommended when freight movement would interfere unduly with passenger service. Consideration shall be given to increasing cabinet height when elevator is used for combination passenger and freight.

g. **Continuity of Service.** When one elevator normally would meet the requirements in a building where elevator service is essential (such as office buildings over four stories high), two shall be installed to ensure continuity of service.

h. **Future Elevators.** The possibility of change in the type of building occupancy and reassignment of building area that would result in a greater volume of passenger traffic shall be investigated. When possibilities exist, the building framing shall be arranged to permit future installation of an additional elevator or escalator equipment to handle future increase in traffic volume.

8.2.2 Freight Elevators.

a. **Classification.**

1) **General Freight.** These are provided to handle the common freight requirements of activities in the building. The material transported by these elevators is distributed throughout the building.

2) **Special Purpose Freight.** These serve the particular requirements of one activity in the building. These elevators form a part of a planned route for handling a specific type of material.

b. **Planning.** When planning the location of freight elevators, the following principles shall be observed:

1) General freight shall be arranged to discharge into a separate vestibule or service lobby at each floor, but shall not discharge into primary routes of horizontal circulation such as main corridors, lobbies, etc.

2) Freight elevators shall be located convenient to the building loading platform or to other facilities provided for bringing freight into the building.

3) A freight elevator shall have a stop at the major mechanical and electrical equipment level(s), including equipment levels of other elevators.

c. **Size and Number.**

1) **Special-Purpose Freight Elevator.** The size and number of special-purpose freight elevators will depend upon information received from the Agency regarding the kind, total load, method of loading, and movement of freight that must be handled.

2) **General Freight Elevators.**

a) The size of general freight elevators shall be adequate for the movement of essential freight, including relocatable partitions. The platform size shall be not less than 8 feet wide by 12 feet deep. A larger size, adequate far the intended use, shall be provided wherever investigations shows that the elevator shall be used to move mechanical equipment, fork lift trucks, or other materials. Horizontal sliding type doors shall be provided.

b) At least one general freight elevator shall be provided in office buildings that have a gross area of 250,000 square feet or more, and have three stories or more above ground. The installation of a freight elevator shall be made when the conditions of occupancy indicate that service is needed regardless of the size of the building.

c) The provision of more than one freight elevator shall be considered in buildings of over 800,000 gross square feet, when dictated by special known requirements, or by the building design.

d. **Capacity and Speed.**

1) Freight elevators shall have a minimum capacity of 8,000 pounds, and shall be designed for one of the Class C loadings described in the A17.1 Code. Elevators required to carry loads in excess of 6,000 pounds, or in which heavy trucks shall be used, should have capacities to handle the maximum required loads. Class Cl loading, where trucks are carried, shall be adequate for Federal buildings.

2) Freight elevators shall have a car speed in proportion to the number of floors served.

e. **Continuity of Service.** If continuity of service is necessary, two freight elevators shall be installed, even if normal service demands are handled satisfactorily with one.

8.2.3 Elevator Hoistways.

a. **Framing.** The hoistway shall be free of projections. Framing projections which occur shall have guard plates as required by the A17.1 Code. Structural supports shall be provided at each floor and, where conditions require, between floors for securing guide rail brackets. Depending on the size and capacity of elevators, provide either intermediate supports between floors or guide rail backing for larger guide rails where the distance between floors or the structural supports exceeds 14 feet. Provide intermediate supports for elevators with moderately large platforms, large capacity, or those designed for Class C loading when the floor heights are less than 14 feet. Concrete hoistways or specially designed steel H-column supports for each elevator car guide rail, extending the full height of the hoistway, are required for heavy duty freight elevators designed for Class C loading or one-piece loading. Each project shall be checked to ensure that it includes necessary guide rail supports to conform to the above requirements and to Section 200 of the A17.1 Code. Additional supports for guide rails shall be included as a part of the structural framing of the building.

b. **Enclosures.**

1) Elevator hoistway enclosures shall be of fire-resistant construction. The interior

face of hoistway enclosure walls shall have a smooth, flush, light-colored surface, equivalent to well-pointed smooth face tile or brick, or smooth concrete. Sprayed-on fireproofing shall not be used in the elevator hoistway and machine rooms.

2) New buildings and nonbearing hoistway enclosure walls of normal height (14 feet maximum unless otherwise noted) enclosing floor openings over 10 square feet in area shall be stable and have a 2-hour fire rating.

3) For hoistway enclosure walls of abnormal height, check with the structural engineer for stability and possible increase in thickness of material.

c. **Hoistway Ventilation.** Hoistway ventilation shall be provided for venting smoke and hot gases to the outside air in accordance with the Basic Building Code, National Building Code, Standard Building Code, or the Uniform Building Code. (Note: This is rule 100.4 in ASME A17.1 Code).

8.2.4 Elevator Pits.

a. **Depth Requirements.**

1) Pit depths should comply with the A17.1 Code requirements.

2) Freight elevators, that have counterbalancing vertical sliding doors at the lowest landing, shall have a pit depth of not less than half the height of the door plus 6 inches to accommodate the lower floor panel.

b. **Access.** (Rule 106.1d, A17.1)

1) Each pit with a depth between 3 feet and 8 feet shall be provided with a fixed vertical steel access ladder. The ladder shall be located within reach of the elevator hoistway entrance at the bottom landing and to clear elevator equipment.

2) Pits 8 feet deep and over shall be provided with a permanent means of external access, preferably a stairway and door to each pit. Where a permanent means of access is impractical, a permanent ladder, accessible from the hoistway entrance at the bottom, shall be provided in each pit; however, the external access must be very carefully studied before it is declared impractical.

3) Adjacent pit spaces shall be separated by a 7-foot high wire mesh partition.

4) Doors to pit spaces shall be of fire-resistant construction, and shall be provided with self-closing, self-locking hardware, arranged so that a key is required for entry. The doors shall swing out, and offer no impedance to exiting.

c. **Fire-Resistance Requirements.** Where the elevators in one bank or one group of elevators are located in two separate fire-resistant hoistways, the pit space for the group of elevators shall be similarly divided into two fire-resistant units.

8.2.5 Elevator Machine Rooms.

a. **Location.** The placing of electric traction elevator machines in basement machine rooms, or in machine rooms adjacent to the shaft, shall be avoided. This type of installation is not economical, as both first cost and recurring cost for maintenance and power are higher than overhead machines.

b. **Features.**

1) Machine rooms in new buildings shall be large enough to install the elevator equipment, including space for disconnecting means, etc. Allow clearances for control equipment not less than required by the NEC, and with enough working space between the various items of equipment for maintenance purposes. In general, provide not less than 3 feet as the absolute minimum clearance between items of equipment. In new buildings, it shall be possible to remove major equipment components of one elevator far repair without dismantling components of an adjacent elevator. In existing buildings, it may not always be feasible to expand the elevator machine room so as to house the new equipment in accordance with the A17.1 Code.

2) Space shall be provided in machine rooms for tool cabinets, spare-parts cabinets, and lubricant racks or cabinets.

3) Elevator machine rooms shall be of fire-resistant construction. The machine room floor, ceiling, and walls shall have a smooth surface. Exposed sprayed-on fireproofing shall not be used in elevator machine rooms and hoistway. Walls, ceilings, and floors shall be painted a light color.

4) Openings in the floor for passage of moving ropes, etc. shall have 2-inch-high concrete curbs or extended metal sleeves.

5) In buildings where elevator mechanics will be employed, shop space shall be

provided. If there is more than one machine room in the building, this shop space shall be provided in one location only.

c. **Provisions for Removal of Equipment.**

1) If there is more than one elevator in a machine room, the freight elevator shall serve the machine room level. If not, a trap door shall be provided in the machine room floor to allow lowering of elevator equipment to the top floor served by the elevator. A trolley or hoist beam able to support the largest item of the elevator equipment shall be provided over the trap door and over each hoisting machine for removal of equipment.

2) In existing buildings, where there is only one elevator in the building, provisions shall be made so that major equipment components can be moved for repairs. Removal to the roof of the building, and then to the ground, by crane may be necessary.

d. **Access.** (Rule 101.3, A17.1 Code)

1) **Entrance Door.** The elevator machine room door shall be the self-closing, self-locking type provided with a cylinder lock that requires a key for entry. The door shall swing out and offer no impedance to exiting.

2) **Stairs.** Stairs shall be provided for convenient access to machine rooms in accordance with the A17.1 Code.

e. **Noise Control.**

1) **Acoustical Classification.** Machine rooms are classified as Class X space. Machine rooms that are on the same level with offices or similar spaces shall be provided with partitions of sufficient sound attenuation to prevent objectionable noises from reaching the occupied spaces, and shall be located as far as possible from them.

2) **Vibration and Sound Isolation.** Geared machines and motor generator sets shall be mounted on vibration and sound isolating devices.

f. **Skylights.** Skylights shall not be installed in elevator rooms.

g. **Heating.** Heating shall be provided in elevator machine rooms as required.

h. **Ventilation.** Machine rooms shall be provided with ventilation as to limit space temperature rise to 10º F.

8.2.6 Escalators.

a. **Planning.** When vertical transportation is required for a large volume of traffic, escalators shall be installed to supplement elevators. Their use shall be justifiable for buildings with large floor areas, buildings with entering traffic at two or more levels, and service to special areas such as cafeterias and auditoriums. Escalators shall not be installed as a substitute for fixed stairs or as a substitute for elevators. If installed, they shall be in addition to, not in place of, required means of vertical movement.

b. **Location.** Escalators shall be located convenient to building entrances or cafeterias, auditoriums, etc., and shall be located where they are prominently in view between elevators and building entrances so that a maximum portion of the total traffic will be diverted to them. It is recommended that escalators be located in a crisscross arrangement. Where escalators serve three or mare floors, they shall not be installed where the structure depth encroaches on the clearance of the ceiling height below.

c. **Comparison with Elevators.** One escalator provides circulation at any one time in only one direction and only to one additional floor, while an elevator provides service in both directions to all floors. Most individuals with physical disabilities cannot safely use an escalator. Two escalators are needed for two-way traffic, i.e., four escalators are required to serve three floors for two-way traffic. When considering whether to use escalators in a building, the overall annual cost of providing the required service with elevators shall be compared, and Use most economical arrangement selected.

d. **Size and Number.**

1) Escalators shall have a width of 32 inches or 48 inches with an angle of inclination of 30 degrees and tread speed of 90 fpm. The capacity rating shall be 5,000 persons per hour based on a theoretical maximum loading of 1-1/4 persons per 32-inch tread or 8,000 persons per hour with two persons per 48-inch tread.

2) The actual design capacities in persons per hour and in persons per 5 minutes traffic peak to be used in estimating escalator requirements are as follows:

Escalator Width	**Capacity in Persons/Hour**	**Capacity in Persons/5 Min**

32 inches	3,000	250
48 inches	4,800	400

3) In determining the size and number of escalators, passenger elevators shall be considered to ensure proper quantity of service required to handle maximum peak.

4) When escalators are provided for special purposes, to serve auditoriums and cafeterias, the number and size shall be based on estimated peak movement of traffic determined from similar existing installations.

8.2.7 Dumbwaiters.

a. **Classification.**

1) Floor loading type.

2) Counter loading type.

b. **Planning.** Dumbwaiters shall be located convenient to the areas served, preferably in a position where the hoistway construction will not interfere with space use.

c. **Size and Number.** Dumbwaiter platform area and height must be adequate to permit convenient loading and unloading of materials. The number of dumbwaiters to be installed shall be based on the estimated volume of material to be handled.

d. **Capacity and Speed.** The dumbwaiter load capacity shall be adequate to handle the maximum anticipated car loading. Kitchen and library dumbwaiters have capacities of 500 pounds. Floor loading type dumbwaiters shall be designed to carry food carts, book carts, etc. Food-carrying dumbwaiters shall be made of stainless steel.

e. **Types.** Dumbwaiters shall be of the power-operated type.

f. **Hoistways.**

1) **Enclosures.** Dumbwaiter hoistway enclosures shall be of fire-resistant construction with a smooth interior finish.

2) **Entrance Doors.** The dumbwaiter hoistway entrance doors shall be of fire-resistant construction and preferably of divided counterbalanced type. The entrance frames shall be rolled or pressed sheet metal with extended sill on the room side. Stainless steel frames and door panels shall be used for kitchen

dumbwaiters. Doors and frames of sheet steel shall be factory dumbwaiters. Doors and frames of sheet steel shall be factory primed with painted finishing coats applied at the site. Dumbwaiter hoistway entrances located with sills at floor level shall have 1/4-inch thick, nonskid steel plate sill with a reinforced truckable sill on the top of the lower door section. In some installations, doors may be power-operated.

3) **Size and Clearance.** Hoistway sizes and entrance dimensions shall comply with the A17.1 Code. A swing type pit access door is desirable for cleaning out the pit for counterloading type dumbwaiters.

4) **Machine Spaces.** Dumbwaiter machine spaces shall be large enough to permit easy access to the equipment for maintenance purposes. The walls, floor, and ceiling enclosing the machine space shall be of fire-resistant construction.

5) If a hoistway tower is needed, it may consist of double sheet steel panels, each with 18-gauge minimum. It shall be filled with sound deadening and fire-resistant materials.

8.2.8 Wheelchair Lifts.

a. **Classification.**

1) Vertical wheelchair lift.

2) Inclined wheelchair lift.

b. **Planning.** Where ramp or elevator installations for use by individuals with physical disabilities are impractical, vertical and/or inclined wheelchair lifts shall be considered. The number and location of such lifts depend an the general architecture of each building, and shall be determined on an individual project basis.

c. **Features.** The lift shall consist of a 12-square-foot horizontal platform enclosed by a combination of panels, railings, doors, a lifting mechanism to raise and lower the platform, and suitable control and safety devices.

d. **Vertical Wheelchair Lift Performance.**

1) Maximum rise shall not exceed 6 feet.

2) Capacity shall be 450 pounds.

3) Maximum speed shall be 30 fpm.

e. **Inclined Wheelchair Lift Performance.**

1) Maximum angle shall be 45 degrees.

2) Maximum travel shall not exceed 35 feet (measured on the incline), and not more than two consecutive floors.

3) Capacity shall be 450 pounds.

f. **Restrictions.**

1) Lifts shall not be installed where lobby areas and inclined areas are greatly reduced or where they present a hazard.

2) Inclined lifts shall not be installed on stairs with low headroom clearance.

3) When inclined lifts are installed on egress stairs, lifts shall not encroach on the required units of egress.

8.2.9 Exterior Power Platforms.

a. **Planning.** Exterior power platforms, for window washing and for other maintenance, shall be determined on an individual project basis.

b. **Architectural and Structural Limitations.** The provisions of an acceptable powered platform may restrict, to a minor degree, the freedom that would otherwise be available in the architectural and structural design of the building.

c. **Safety Requirements.** Each powered platform installation shall be designed, installed, inspected, and tested in accordance with the latest edition of the American

National Standards Safety Requirements for Powered Platforms for Exterior Building Maintenance.

d. **Mechanical Design Features.** Powered platforms shall be designed to incorporate the following basic safety and operating features:

1) Roof cars shall be gravity stable, considering both overturning moment and wind loading, with an adequate safety factor. This requirement dictates a lightweight working platform and a relatively heavy roof car. Tiedowns or safety brackets on the roof car shall be considered only as an additional safeguard to prevent overturning. Roof car track and wheels shall be designed to minimize noise which might be annoying to occupants of the building.

2) Working platforms shall be supported by four wire ropes, equipped with approved means to detect and prevent over or under tensions in any rope, attached at or near each end of the platform. Platform working area shall be clear. Support ropes shall be located in front of surfaces to be washed.

3) Working platforms shall be steadied against the building face to prevent swaying in gusts of wind, or when workmen press against the building in the process of washing windows or making other repairs. Fixed guides are required in the face of the exterior of buildings, 130 feet and over in height, to accomplish this purpose. The working platform shall travel only in the level position.

4) The equipment shall be operable by a single worker. It shall not require any standby worker on the roof car, or elsewhere, while in use. Sometimes two workers may be used on the working platform to perform the washing or maintenance operation.

5) Operation and control provisions shall be as nearly fail-safe as practical. Protective devices such as limit switches shall be provided to minimize the possibility of malfunction or improper operation. Operating buttons shall be of the deadman type.

6) The main power supply outlets for the power platform located on the roof shall be of a type to prevent hazard to workers during all weather conditions.

7) Telephone connections shall be provided for help in the event of power failure, control failure, or similar emergency. Rescue provisions shall be included to permit manual lowering of the platform or to facilitate removal of workers trapped on a platform.

e. **Coordination.** The designer shall coordinate to ensure that the architectural and structural design will accommodate the different manufacturers' equipment. Loads imposed by the power-operated platform on the roof structure, parapet, mullions, exterior walls, or vertical guides shall be considered in the design. A garage shall be provided on the roof to protect the equipment during periods of inclement weather. This garage will improve the appearance of the building when the power-operated platform is not in use, and will facilitate maintenance of the equipment.

CHAPTER 9. BIOHAZARD CONTAINMENT DESIGN
PART 1. GENERAL

9.1.1 **Scope.** This chapter provides general guidance in designing biological containment facilities that support research at the BL 3 and BL 4 physical containment levels. Its primary objective is to provide the best possible physical containment of hazardous microorganisms or biological agents through incorporation of equipment and facility safeguards in the design of the facility.

9.1.2 **Objectives.** The objectives of the containment facility is to protect investigators, all support staff, and occasional visitors from accidental laboratory acquired infection(s); prevent release of infections, microorganisms, or toxic chemicals to the atmosphere which may pose a threat to community members, livestock, or the environment itself; and prevent cross-contamination of research materials and research animals.

9.1.3 **Basic Requirements.** The design shall comply with applicable codes and standards governing the work and other requirements described in Chapter 1.

9.1.4 **Biohazard.** (A contraction of the words biological and hazard). A Biohazard is defined as an infectious agent(s), or part thereof, presenting a real or potential risk to human, other animals, or plants, directly through infection or indirectly through disruption of the environment.

9.1.5 **Facility Barrier Control Measures.** To establish zones for containment of hazardous biological agents, their by-products, and chemical compounds, the facility is constructed with levels of barriers that serve as protective zones to meet the objectives stated above. See Figure 9-1 for diagrammatic relationship of primary and secondary barriers.

a. **Primary barriers.** Equipment safeguards and laboratory practices provide the primary barriers for containment of hazardous biological agents. They are the first line of defense for preventing escape and possible spread of the research materials. Examples of primary barriers are biological safety cabinets, closed ventilated animal cages, safety centrifuge cups, and safety blenders.

b. **Secondary barriers.** These are features of the facility which surround the primary barriers and serve to prevent the escape of hazardous agents to the environment outside of the laboratory or building in the event of a failure in a primary barrier. Examples of secondary barriers are the floors, walls and ceilings, air locks and door barriers, differential pressures and directional airflow, exhaust air filters, and provisions for treating contaminated wastes.

FIGURE 9 - 1

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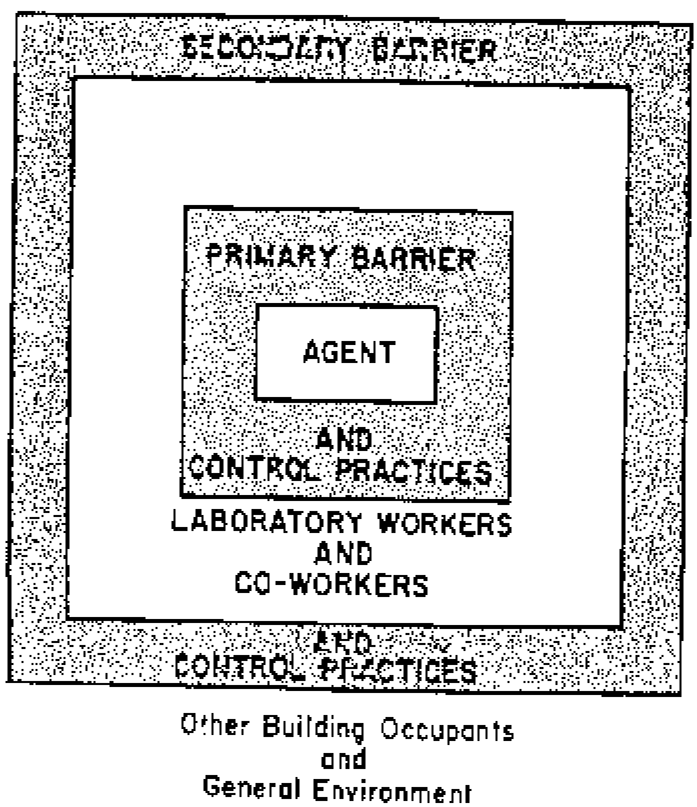
FIGURE 9 - 1

DIAGRAMATIC RELATIONSHIP OF
PRIMARY AND SECONDARY
BARRIERS



c. **Tertiary barriers.** In certain facility design configurations, the spaces surrounding the laboratory function is a tertiary barrier zone. Examples of tertiary barriers are equipment and utility spaces, interstitial spaces housing ventilation duct and utility piping, attics, or double-walled construction surrounding the primary containment zone.

PART 2. HAZARD CLASSIFICATION AND CHOICE OF CONTAINMENT

9.2.1 **General.** To determine the levels of protection a research facility must provide, to protect personnel, animals, plants and the environment from a biohazard, the proposed research must be analyzed and assigned a risk category (Biosafety Levels 1-4). Analysis shall consider factors to include:

Etiological Agents

a. Infectious dose
b. Effectiveness of available vaccines
c. Availability of antibiotic and prophylactic treatment
d. Morbidity and mortality data based on laboratory acquired infections (disease everity)
e. Amount and concentration of research material
f. Biological decay rate
g. Transmissibility via the aerosol route
h. Occurrence in livestock animals
i. Operations
j. Operational practices and procedures
k. Protective equipment and clothing

Chemical Compounds

a. Concentration
b. Amount
c. Toxicity
d. Effects on man or livestock
e. Availability of prophylactic antidotes
f. Environmental effects
g. Availability of neutralizing techniques
i. Etc.

Radioisotopes

a. Half-life expectancy
b. Radiation activity
c. Tolerance levels
d. Research activities
e. Concentration

9.2.2 Biosafety levels.

Four biosafety levels are described which consist of combinations of laboratory practices and techniques, safety equipment, and laboratory facilities appropriate for the operations performed and the hazard posed by the infectious agents and for the laboratory function or activity. These four biosafety level designations are applicable to laboratory and/or animal facilities.

The infectious agents (often referred to as etiologic agents) are identified as four classes. These four agent classes are based on the risk of infection to human or livestock animals.

a. **Biosafety Level 1 (BL1).** Involves agents of no known or minimal potential hazard to laboratory personnel, animals and the environment. Presents no potential economic loss to the animal industries.

b. **Biosafety Level 2 (BL2).** Involves agents of moderate potential hazard to personnel, animals, and the environment with minimal economic loss to the animal industries.

c. **Biosafety Level 3 (BL3).** Involves agents which are indigenous or certain ones that are exotic to the United States which can be contracted via the respiratory route and may cause serious or lethal diseases to man, animals, or cause moderate economic loss to the animal industries.

d. **Biosafety Level 4 (BL4).** Involves highly dangerous and exotic agents which pose a high individual risk of life-threatening disease to man and food animals. These agents have the potential for severe economic loss to the animal industries.

9.2.3 Choice of containment.

a. Three designs (types) were identified and established internationally for facilities. These facilities can be used for hazardous or potentially hazardous research projects or operations that involve etiological agents and chemical compounds, including radioisotopes with or without research animals. These categories can be classified as: 1) the basic microbiological laboratory, 2) the containment laboratory, and 3) the maximum containment laboratory. The levels of protection increases with the risks associated with the agents under study and, in general, correspond with levels of containment required for low risk, moderate risk, and high risk agents or procedures respectively. The following table provides the recommended type of containment/facility to use with research materials of different hazard levels.

Agent or Compound	**Facility Type Recommendation**
Human and Animal Pathogens	
Class 1 Agent	Basic Facility
Class 2 Agent	Basic Facility
Class 3 Agent	Containment Facility
Class 4 Agent	Maximum Containment Facility
Oncogenic (Cancer) Viruses	
Low Risk Viruses.	Basic Facility
Moderate Risk Viruses	Containment Facility
High Risk Viruses	Maximum Containment Facility
Chemical Compounds . . . . (Includes carcinogens and radioisotopes)	Containment Facility or Maximum Containment Facility
Organisms Containing Recombinant DNA and/or RNA Molecules	
BL1 Classification.	Basic Facility
BL2 Classification.	Basic Facility
BL3 Classification.	Containment Facility
BL4 Classification.	Maximum Containment Facility

b. **Facility Types:**

1. **The basic laboratory.** This laboratory provides general space in which work is done with viable agents which are not associated with disease in healthy adults. Basic laboratories include those facilities designated at the BL1 and BL2 with class 1 and 2 agents and genetic engineering manipulations at the same designated levels and risk. While work is commonly conducted on the open bench, certain operations are confined to biological safety cabinets.

2. **The containment laboratory.** This laboratory has special engineering features which make it possible for laboratory workers to handle hazardous materials without endangering themselves, the community, or the environment. Containment laboratories include those facilities designed to accommodate activities at the BL3 with Class 3 agents and recombinant DNA or RNA manipulations at BL3. The unique features which distinguish this laboratory from the basic laboratory are the provisions for access control and a specialized ventilation system and generally requires that all laboratory activities be conducted in a primary barrier; e.g., biological safety cabinet or fume hood. The containment laboratory may be an entire building or a single module or complex of modules within a building. In all cases, the laboratory is separated by a controlled access zone from areas open to the public.

3. **The maximum containment laboratory.** This laboratory has special engineering and containment features that allow activities involving infectious agents that are extremely hazardous to the laboratory worker or that may cause serious epidemic disease to be conducted safely. The maximum containment laboratories include those facilities designed as BL4 facilities. Although the maximum containment laboratory is generally a separate building, it can be constructed as an isolated area within a building. The laboratory's distinguishing characteristics is that it has secondary barriers and often tertiary barriers to prevent hazardous materials from escaping into the environment. Such barriers include sealed openings into the laboratory, air locks or liquid disinfectant barriers, a clothing change and shower room contiguous to the laboratory, a double door autoclave, a biowaste treatment system, a separate ventilation system, and a HEPA filter system to decontaminate exhaust air.

PART 3. PRIMARY BARRIER (CONTAINMENT EQUIPMENT)

9.3.1 **General.** Biological safety cabinets (BSC) are the principal equipment used to provide physical containment. They are used as primary barriers to prevent the escape of aerosols into the laboratory environment. Certain cabinets can also protect the experiment from airborne contamination. The selection of BSC is based on the potential hazard of the agent used in the experiment, the potential of the laboratory technique to produce aerosols, and the need to protect the experiment from airborne contamination. The description, capabilities, and limitation of these cabinets follows.

9.3.2 **BSC application.** The following table is a summary of the type biological safety cabinets (BSC) to use with research material of different hazard levels.

	Hazard Levels									
Type BSC	Oncogenic (Cancer) Viruses		Etiologic Agents (Human/Animal Pathogens)				Organisms with Recombinant DNA and/or RNA			
	Low	Moderate	1	2	3	4	1	2	3	4
Class I	X	X	X	X	X		X	X	X	
Class II	X	X	X	X	X		X	X	X	
Class III	X	X	X	X	X	X	X	X	X	X

9.3.3 **Biological Safety Cabinets.**

a. **Class I.** A ventilated cabinet for personnel and environmental protection, with an unrecirculated inward airflow away from the operator. This cabinet is suitable for work with low and moderate risk biological agents, where no product protection is required. It is an open fronted, negative pressure ventilated cabinet with a minimum inward face velocity at the work opening of at least 75 feet per minute. The exhaust air from the cabinet is filtered by a high-efficiency particulate air (HEPA) filter. See illustration in Figure 9-2. This cabinet may be used in three operational modes:

1. With a full-width open front.

2. With an installed front closure panel (having four 8-inch diameter openings) not equipped with gloves.

3. With an installed front closure panel equipped with arm-length rubber gloves.

b. **Class II.** A ventilated cabinet for personnel, product, and environmental protection having an open front with inward airflow for personnel protection, HEPA filtered laminar airflow for product protection, and HEPA filtered exhausted air for environmental protection. The design, construction, performance and testing of Class II biosafety cabinet are covered by National Sanitation Foundation (NSF) Standard No. 49, entitled Class II (Laminar flow) biohazard cabinetry (available from NSF, 3475 Plymouth Road, P.O. Box 1468, Ann Arbor, Michigan 48106; Phone 313-769-8010). All Class II cabinets purchased for ARS projects will be built to fully meet Standard 49 and bear the NSF listed mark. All cabinets purchased and installed in a facility will be tested by a recognized, independent testing firm acceptable to ARS after complete installation of the cabinet to comply with the certification requirements specified in NSF Standard 49.

NOTE: When toxic chemicals or radionuclides are used as adjuncts to biological studies or pharmaceutical work, Class II cabinets designed and constructed for this purpose should be used.

1. **Type A.** (Formerly designated Type 1): Cabinets that: (a) maintain a minimum calculated average inflow velocity of 75 fpm through the work area access opening; (b) have HEPA filtered downflow air from a common plenum (i.e., plenum from which a portion of the air is exhausted from the cabinet and the remainder supplied to the work area); (c) may exhaust HEPA filtered air back into the laboratory; and (d) may have positive pressure contaminated ducts and plenums. Type A cabinets are suitable for work with low to moderate risk biological agents in the absence of volatile toxic chemicals and volatile radionuclides. See illustration in Figure 9-3.

2. **Type B1.** (Formerly designated Type 2): Cabinets that: (a) maintain a minimum (calculated or measured) average inflow velocity of 100 fpm through the work area access opening; (b) have HEPA filtered downflow air composed largely of uncontaminated recirculated inflow air; (c) exhaust most of the contaminated downflow air through a dedicated duct exhausted to the atmosphere after passing through a HEPA filter; and (d) have all biologically contaminated ducts and plenums under negative pressure, or surrounded by negative pressure ducts and plenums. Type B1 cabinets are suitable for work with low to moderate risk biological agents. They may also be used with biological agents treated with minute quantities of toxic chemicals and trace amounts of radionuclides required as an adjunct to microbiological studies if work is done in the direct exhausted portion of the cabinet or if the chemicals or radionuclides will not interfere with the work when recirculated in the downflow air. See illustration in Figure 9-3.

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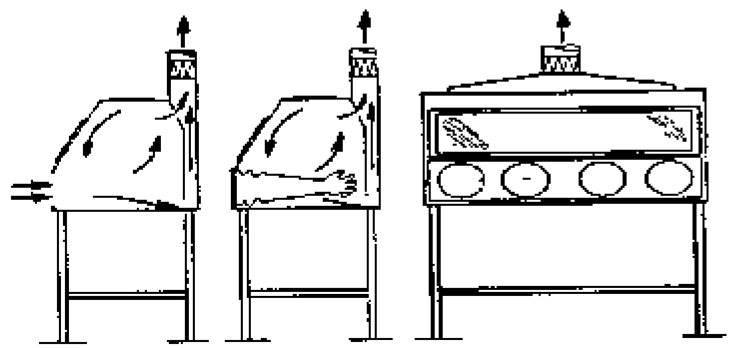
FIGURE 9 - 2

CLASS I CABINET



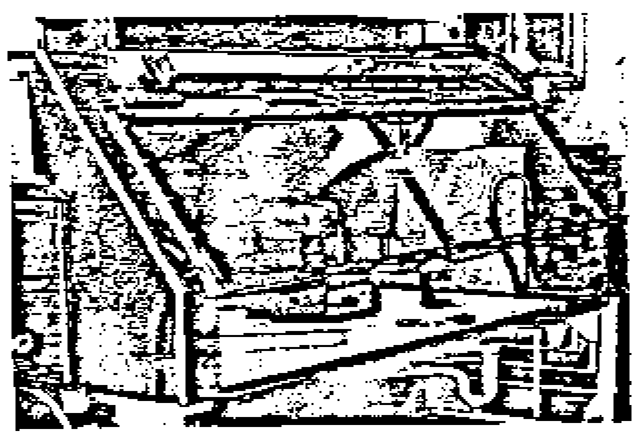


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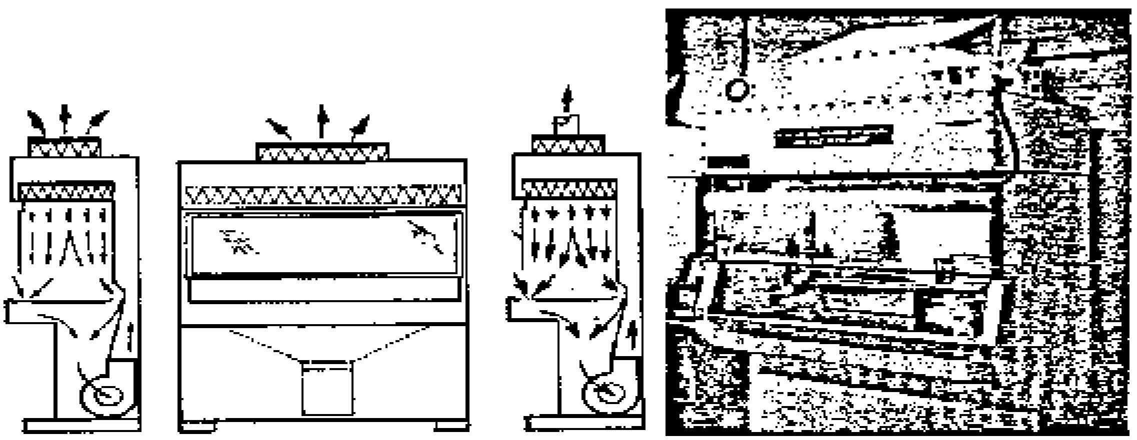
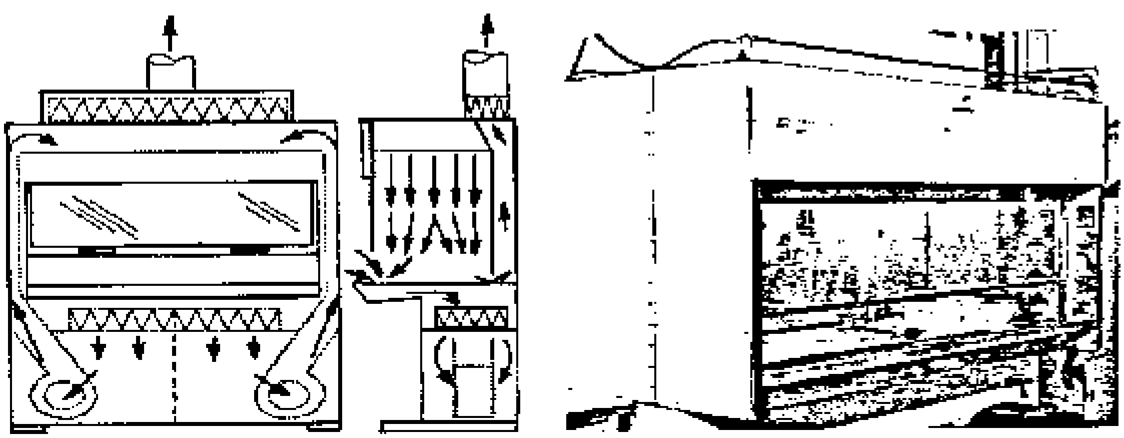
FIGURE 9-3

CLASS II CABINETS



TYPE A



TYPE B1

9-10

3. **Type B2.** (Sometimes referred to as "Total Exhaust"): Cabinets that: (a) maintain a minimum (calculated or measured) average inflow velocity of 100 fpm through the work area access opening; (b) have HEPA filtered downflow air drawn from the laboratory or the outside air (i.e., downflow air is not recirculated from the cabinet exhaust air); (c) exhaust all inflow and downflow air to the atmosphere after filtration through a HEPA filter without recirculation in the cabinet or return to the laboratory room air; and (d) have all contaminated ducts and plenums under negative pressure, or surrounded by directly exhausted (nonrecirculated through the work area) negative pressure ducts and plenums. Type B2 cabinets are suitable for work with low to moderate risk biological agents. They may also be used with biological agents treated with toxic chemicals and radionuclides required as an adjunct to microbiological studies.

4. **Type B3.** (Sometimes referred to as "Convertible Cabinets"): Cabinets that: (a) maintain a minimum (calculated or measured) average inflow velocity of 100 fpm through the work access opening; (b) have HEPA filtered downflow air that is a portion of the mixed downflow and inflow air from a common exhaust plenum; (c) discharge all exhaust air to the outdoor atmosphere after HEPA filtration; and (d) have all biologically contaminated ducts and plenums under negative pressure, or surrounded by negative pressure ducts and plenums. Type B3 cabinets are suitable for work with low to moderate risk biological agents treated with minute quantities of toxic chemicals and trace quantities of radionuclides that will not interfere with the work if recirculated in the downflow air.

c. **Class III.** A totally enclosed, ventilated cabinet of gas-tight construction. Operations within the cabinet are conducted through attached rubber gloves. When in use, the cabinet is maintained under negative air pressure of at least 0.5 inches water gauge (in. wg). Supply air is drawn into the cabinet through HEPA filters. The exhaust air is treated by double HEPA filtration, or by HEPA filtration and incineration. See illustration in Figure 9-4.

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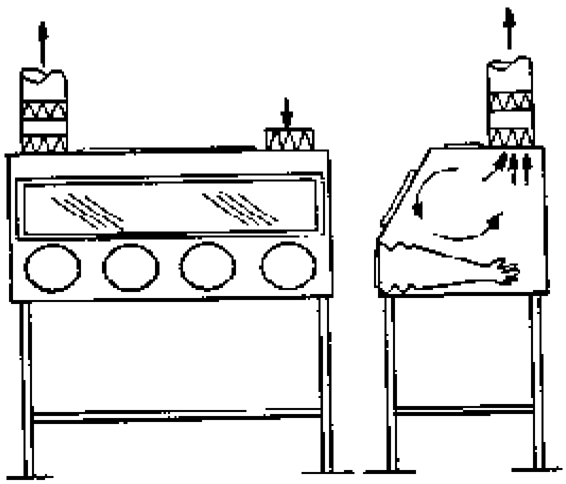
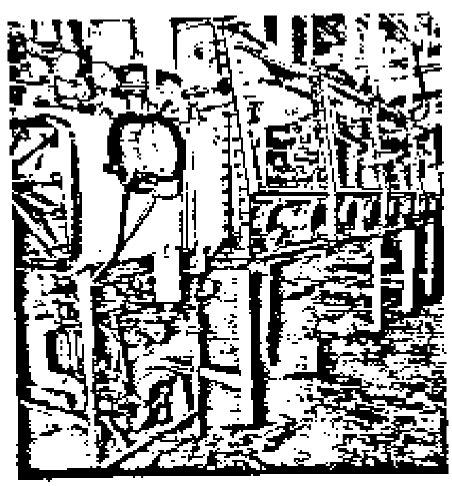
FIGURE 9-4

CLASS III CABINET





PART 4. SECONDARY BARRIERS (FACILITY DESIGN FEATURES)

9.4.1 **General.** Special engineering and containment features when applied and incorporated in the design of biological facilities provide additional protection and secondary barriers against the possible contamination of the immediate and general environment beyond the laboratory in use. The following describes the design features for basic laboratory, containment laboratory, and maximum containment laboratory.

9.4.2 **Biosafety Level 1 and 2 (BL1 and BL2).** The BL1 and BL2 are basic microbiology laboratories where the potential hazards associated with the research materials can be controlled by ordinary laboratory practices. The laboratories are of conventional design and are not characterized by special engineering features for containment. Biological safety cabinets should be provided for work with potentially hazardous materials when open bench work practices do not provide adequate protection for the laboratory worker. See illustrations in Figures 9-5 and 9-6.

The BL1 and BL2 laboratories should provide an internal environment which is easily cleanable. The walls and floors should be surfaced with or be constructed of materials which can withstand detergent cleaning solutions and disinfectants. Horizontal surfaces which may serve as dust collectors should be minimized and suspended fixtures, such as fluorescent lighting, and exposed service piping should be accessible for cleaning. Bench tops should be impervious to liquids and resistant to acid, alkali, organic solvents, and moderate heat.

Laboratory furniture should be sturdy and readily cleanable. Voids in laboratory furniture groupings should be accessible for cleaning. Open shelving should be avoided; closed cabinets provide a better environment in which contamination can be controlled.

Although the primary consideration in the arrangement of the laboratory furnishings is that it should suit the research program, floor plans should include environmental control and safety considerations. Work spaces should be planned to be out of through traffic areas. If biological safety cabinets are provided they should be located deep in the laboratory, preferably at "dead ends" where traffic will not disturb the air balance of the cabinets. Established traffic patterns should also minimize the proximity of clean and contaminated operations. Extraneous traffic

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FIGURE 9-5

A BASIC FACILITY

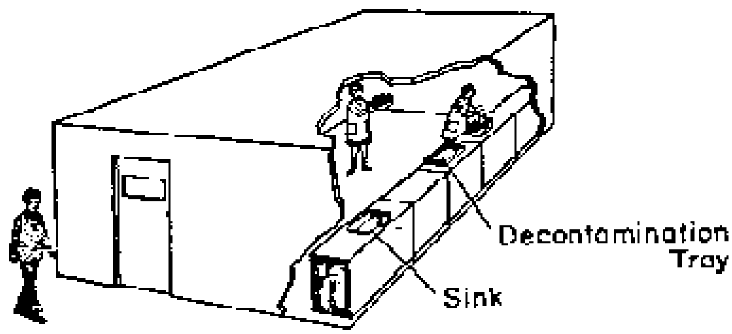
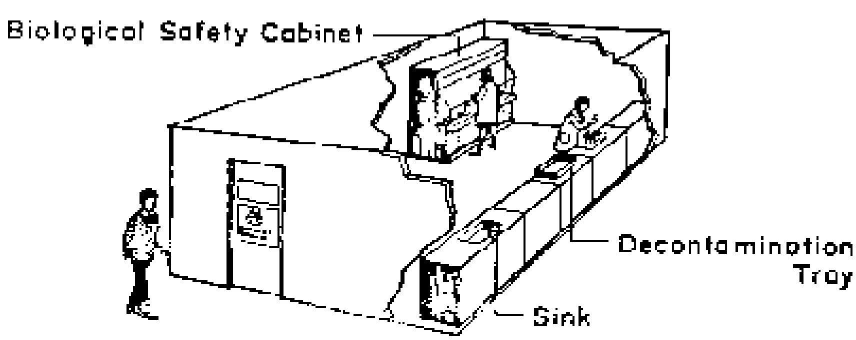


FIGURE 9-6

A BASIC MICROBIOLOGY LAB



should be reduced. Office areas should not be included in the laboratory and doors should be closed with self closing devices to reduce and control the egress of non-laboratory personnel. For contamination control, hand washing facilities should be located near the laboratory door.

For summary of general containment guidelines for BL1 and BL2 laboratories see Table 9-1.

Mechanical ventilation may be provided but is not necessary for BL1 and BL2 laboratories. The laboratories may have operable windows providing they are fitted with insect screens. Mechanically provided air, either from building ventilation systems or individual heating/air conditioning units, may be recirculated within the laboratory and exhausted without treatment in certain research operations. Treated exhaust air from Class II biological safety cabinets may be returned to the laboratory environment. Laboratory and cabinet air exhausted to the outdoors should be dispersed to the atmosphere in a manner to clear occupied buildings and air intakes.

An autoclave must be available for the sterilization of wastes and contaminated materials generated within the laboratory. In practice, wastes from BL1 and BL2 laboratories are usually decontaminated at a site remote from the laboratory. It is essential that this site be located within the same building in which the BL1 and BL2 laboratories are located.

9.4.3 **Biosafety Level 3 (BL3).** A BL3 facility may be a single laboratory or a suite of laboratories and support areas designed for handling of moderately hazardous agents (Class 3 agents, moderate risk oncogenes, BL3 recombinant organisms, and toxic chemical compounds) or materials. The unique features which distinguish the BL3 facility from the BL1 and BL2 facilities are the provisions for access control, safety equipment, and a specialized ventilation system. See illustrations in figures 9-7 and 9-8.

For access control, the BL3 laboratory or facility should be completely separated from classrooms, general offices, receiving areas and other areas where there is ready access to the public and corridors available to normal traffic flow of laboratory personnel who do not work with the BL3 facility. Various arrangements used to achieve this separation include partitioning the corridor for a BL3 laboratory at the blind end of the corridor, entrance through another laboratory, a double door system where entry to the BL3 laboratory is through an anteroom or air lock, or entrance through a change room and shower facility. The change room and shower facility arrangement provide the greatest access control of any of the examples.

Like the BL1 and BL2 laboratory, the BL3 laboratory should be constructed and furnished to provide work surfaces which will facilitate cleaning, prevent accumulation of contamination, and are impermeable to liquids. Materials selected should satisfactorily withstand detergents, disinfectants and decontamination with gaseous formaldehyde. Exposed horizontal utility pipes and ductwork, and open storage cabinets, should be kept to a minimum or eliminated entirely, where possible.

The BL3 laboratory should be constructed so that it can be sealed to permit gas decontamination and fumigation. All utility pipe and duct penetrations, electrical conduits, utility access and other passages through floors, walls and ceilings should be sealed or capable of being sealed to assure isolation of the space environment. If dropped ceilings are installed to conceal air ducts and utility distribution lines, they should be monolithic, or constructed of plastic or dry wall or similar materials. All ceiling joints should be taped, sealed and painted to make them impervious. If windows are provided for the BL-3 laboratory, they must be made inoperable and sealed in the shut position. All laboratory doors must be self-closing. A foot, elbow or automatically operated hand washing facility must be situated near each exit from the containment area.

Provision for dealing with maintenance problems should be incorporated into BL3 laboratory design. Where possible, compressor monitors or gas supplies which can be isolated should be made accessible from outside the laboratory. It is recommended that compressed gas cylinders supplying carbon dioxide, nitrogen and other gases be stored outside the laboratory and that manifold piping be used to provide the gases inside the area. Because of problems associated with radiological and biological contamination of pipelines and the potential for exhaust air contamination, central vacuum systems are not recommended. Provision should be made for the use of small individual vacuum pumps for use within the containment laboratory.

Each BL3 laboratory or module in a BL3 facility should contain a biological safety cabinet appropriate for use with moderately hazardous agents. Current concepts of biological and industrial hygiene control indicate that potentially hazardous procedures should be confined to ventilated safety cabinets. There are few operations which could be considered risk free at this level of containment. Good laboratory practice demands that protective cabinets be used whenever hazardous materials are handled outside fully contained vessels.

A mechanical ventilation system capable of controlling air movement must be provided for a BL3 laboratory. Balance of the supply air and exhaust air should provide a directional airflow with the air drawn into the laboratory through the entry area. Recommendations to create this infiltration include a 15 percent differential between exhaust and supply or sufficient exhaust to create an 0.05 inch water column differential between the laboratory and the access area; whichever the criterion, it is recommended that the infiltration of air into the laboratory be at least 50 cubic feet per minute per doorway leading into the research space under all operating conditions. Within the BL3 laboratory or laboratory suite, the supply and exhaust systems should be distributed and balanced in a manner that the flow of air between activity locations or functional spaces is in the direction of increasing potential laboratory hazard.

The air supply/exhaust system may be part of the building system provided certain precautions are taken. The building exhaust systems may be used if the air from the laboratory is not recirculated to other areas of the building. Exhaust air can be discharged to the outdoors without filtration or other treatment provided it is dispersed to the atmosphere in a manner that clears occupied buildings and air intakes. This is usually accomplished by locating the exhaust stacks on the roof and exhausting upward at a high velocity (e.g. > 2500 fpm). Supply air systems must be designed to prevent the positive pressurization of the laboratory and the reversal of airflow from the laboratory to clean areas of the building. A device for monitoring airflow, and possibly an alarm, should be provided to alert the laboratory to an exhaust air problem. In rare circumstances, recirculation of the air is permitted within the individual laboratory space if the air is filtered by HEPA filters.

The treated (HEPA filtered) exhaust air from Class II type A "laminar flow" biological safety cabinets may either be returned to the laboratory environment or discharged to the outdoors. Class I, Class II types B1 and B2 (the new 100 percent exhaust "laminar flow" cabinet), and Class III cabinets usually require external exhaust fans and may be directly connected to a building exhaust system. The treated exhaust from these cabinets must be discharged outdoors. Room supply and exhaust systems and the exhaust systems for these biological safety cabinets must be designed and operated in a manner that avoids interference with the air balance of the laboratory and the cabinet.

An autoclave for the decontamination of laboratory wastes should be located within the BL3 laboratory. A double door autoclave with access outside the laboratory or facility provides an excellent method for providing clean/contaminated materials flow. With appropriate procedural controls, an autoclave may be located outside of the BL3 laboratory providing it is located within the same building.

For summary of general containment guidelines for BL3 facility see Table 9-1.

9.4.4 **Biosafety Level 3 Agriculture (BL3 Ag.).** In ARS, special features are required for BL3 facilities when research involves certain Class 3 etiologic agents and recombinant organisms (animal or plant), large species of animals, exotic strains of endemic diseases, and exotic diseases of livestock. To accommodate research for the above identified microorganisms and animals previously described, BL3 facilities are modified to include select features from maximum BL4 facilities. The special BL3 facility for use in ARS is designed as a **Biosafety Level 3 Agricultural facility.** The basic, **mandatory** design changes include personnel change rooms; personnel and equipment air locks; a double-door autoclave; single pass, directional, and pressure gradient air system; HEPA filtration of supply and exhaust air with special electrical interlocks to prevent pressurization of the BL3 zone during electrical or mechanical breakdowns; a central liquid waste water sterilization system; sealed interior surfaces (walls, floor, ceiling) capable of passing a leak rate established by ARS; airtight ducts or hollow doors with hinges or latch/knob areas sealed; air pressure gasket doors; restraining devices on animal rooms; and a necropsy room and pathological incinerator if research involves traps and HEPA filtration of atmospheric vents.

The BL3 Ag facility is usually a separate zone within a building or a separate building, with controlled access, special physical security measures, and functions as a box within a box principle. The details of the above identified components for the BL3 Ag facility are covered under the BL3 and BL4 narrative sections and design considerations. The BL3 Ag facility requires special testing and certification procedures which are detailed in the remaining parts of this chapter. A BL3 facility is very limited and is only to be provided for research locations where the mission warrants this type of facility. A BL3 Ag facility is not BL4 and should not be designated as such. Basically, the need for a BL3 Ag facility is necessary when the facility itself serves as the primary barrier zone (containment box) to house research animals or other materials for Class 3 etiological agents (epizoonotic or zoonotic that are readily transmissible via the aerosol route and are judged to have a high risk factor) or exotic strains of endemic diseases or exotic diseases of livestock or plants. A special feature of a BL3 Ag facility is that several normally referred to secondary

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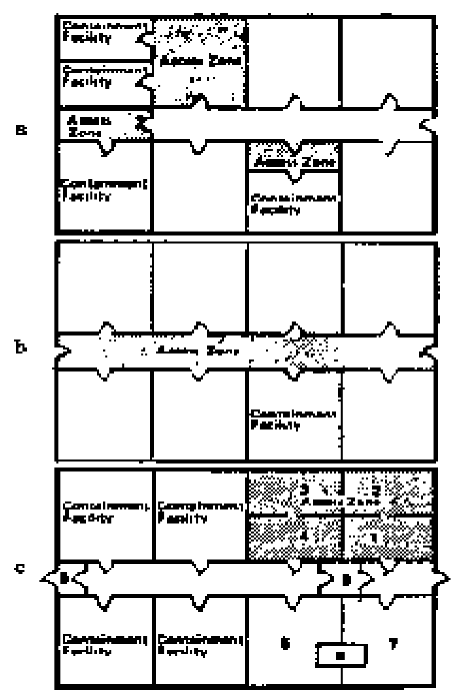
FIGURE 9-7

REPRESENTATIVE CONTROLLED ACCESS ZONES FOR CONTAINMENT FACILITIES

Figure a illustrates three approaches to separating a single module containment facility from a common-use corridor.

Figure b depicts a corridor as the access zone. This approach is acceptable but undesirable unless strict access control can be ensured.

Figure c shows the access zone as a change room and shower facility. Access to the containment facility is by passage from the clean clothing-change room through the drying room, shower room, and "contaminated" clothing-change room. This traverse is reversed for egress. In this example, the airlocks are used only for the passage of equipment, materials, or supplies into the containment facility.



1 Clean Clothing Change Room
2 Drying Room
3 Shower Room
4 Contaminated Clothing Change Room
5 Contaminated Waste Handling Room
6 Double Door Autoclave
7 Washing Room
8 Air Lock

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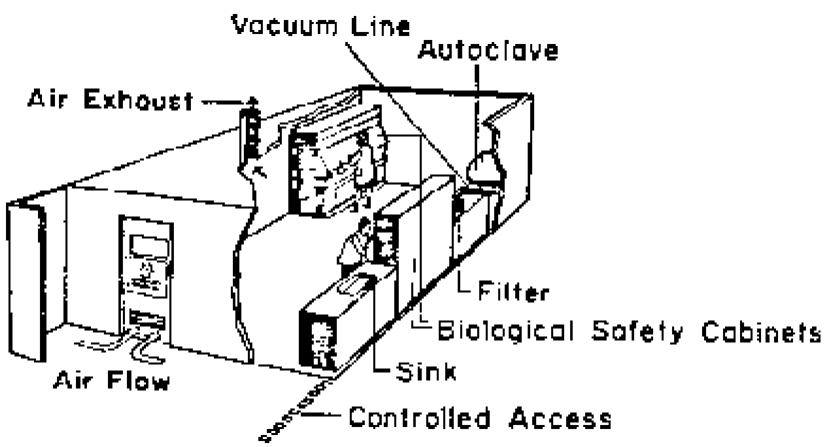
FIGURE 9 - 8

REPRESENTATIVE SINGLE LAB MODULE CONTAINMENT FACILITY



barriers in containment facilities become primary barriers. Examples are sealed interior surfaces (walls, ceiling, floor or contained laboratory and animal rooms), ventilation systems, pathological incinerator, effluent sterilization system, HEPA filters, etc.

For summary of general containment guidelines for BL3 Ag facility see Table 9-1.

9.4.5 **Biosafety Level 4 (BL4).** ARS does not have BL4 facilities and, at this time, does not foresee a need to construct a maximum containment facility. The inclusion of information is generic and intended to make the construction document comprehensive. The BL4 facility is designed to provide for the safe conduct of research involving biological agents that are extremely hazardous to the laboratory worker, or that may cause serious epidemic disease. The distinguishing characteristics of the BL4 facility is the provision of secondary barriers which completely remove or inactivate hazardous agents which may accidentally escape the research environment. The barriers include: (1) physical barriers, such as sealed floors, walls and ceilings; (2) air lock/change room/shower facilities for personnel entry; (3) air locks for supplies and materials; (4) separate ventilation systems with directional airflow; (5) filtration of exhaust air; (6) double door autoclaves to sterilize laboratory refuse; and (7) a sterilization system to treat potentially contaminated liquid wastes. These barriers serve to isolate the laboratory from the surrounding research environment and the neighboring community. See illustrations in Figure 9-9.

BL4 facilities are generally in a separate building but may be constructed in a clearly isolated area within a building. Because of the complexity and expense of the containment, the facility may be divided into research and "clean" support zones. The clean zones provide space for those laboratory operations that do not involve hazardous agents. The areas contain entrance and office rooms, laboratory support rooms for the preparation of materials for use in the laboratory, holding "normal" animals, and washing and sterilizing glassware, media and equipment; and mechanical and electrical rooms which contain as much of the engineering support equipment that can be located outside of the research facility. These support zones are generally on the perimeter of the general research and animal research laboratories that are the protected areas. They provide a buffer zone around the laboratories and are the areas from which personnel and materials enter and leave the laboratories.

The facility is arranged so that personnel ingress/egress is only through a ventilated air lock/change room/shower room. Provision is made for separating street clothing

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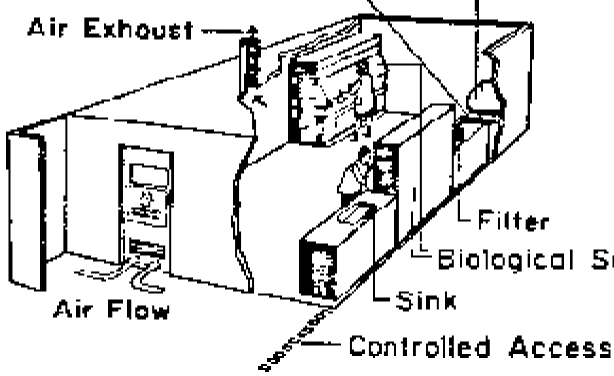
FIGURE 9 - 8

REPRESENTATIVE SINGLE LAB
MODULE CONTAINMENT FACILITY



from laboratory clothing. A double door ventilated vestibule or air lock with optional ultraviolet protection is provided for the passage of supplies and equipment. The doors to these facilities are secured at all times. Emergency exit doors are provided but secured against unauthorized use.

The walls, floors and ceilings of the laboratories are constructed to form an internal shell. Walls are constructed slab to slab and all penetrations are sealed. Exterior windows and vision panels are of safety glass and are sealed. The double door autoclave is located within an exterior wall of the laboratory with the interior door sealed to the barrier wall so that autoclaves maintenance can be performed outside the laboratory zone. The facility is rodent and insect proof and essentially air tight to facilitate fumigation and gas decontamination.

The BL4 laboratories have an independent air supply and exhaust system. The system is operated to provide a negative air pressure within the laboratory area and directional airflow. The directional airflow within the containment area is from areas of least hazard potential toward areas of greatest hazard potential. Manometers are provided to sense the pressure differentials that are established; the manometers are visible inside and outside of the laboratory area and sound an alarm when the differential is disturbed. The air supply and exhaust systems should be interlocked to prevent reversal of directional airflow in the event of exhaust system failure.

The air exhausted from the BL4 laboratories is treated by passage through HEPA filters and is discharged in a manner which will clear occupied buildings and air intake. The general exhaust filters are located as near as possible to the laboratories to minimize the length of contaminated air ducts. The filter housings are designed to facilitate the testing of the filters in place after installation and to permit filter decontamination before removal. Backup filter units and fans facilitate filter changes and provide protection for ventilation system failure. The supply air system may be filtered with 80-90 percent efficiency filters to prolong the life of exhaust filters. Certain circumstances require that the supply air system be equipped with single HEPA filters. It is desirable that the air handling system provide 100 percent fresh air to the facility, and at least 10 room air changes per hour.

The exhaust from Class I, Class II, and Class III cabinets must be HEPA filtered before discharged to the atmosphere. Class III cabinets must be double HEPA filtered or treated by passing through a single HEPA filter, then air incinerated before discharge to the atmosphere.

The double doors of the autoclave provided for the decontamination of materials passing out of the laboratory area should be interlocked so that the outer door can only be opened after completion of the sterilizing cycle and prevent simultaneous opening of both doors. A gas sterilizer, pass-through liquid dunk tank or cold gas decontamination chamber should be provided for the safe removal of material and equipment that are steam or heat sensitive.

Liquid effluents from the BL4 laboratories should be collected and decontaminated before disposal into the sanitary sewers. Effluents from laboratory sinks, cabinets, floors and autoclaves are sterilized by heat treatment. Under certain conditions, liquid wastes from shower rooms and toilets may be inactivated by chemicals.

Vacuum system exhaust and plumbing vents are filtered with HEPA filters.

The primary containment for the laboratory worker in the BL4 laboratory is usually provided by the use of Class III cabinets. These are totally enclosed ventilated cabinets of gas-tight construction. Operations within these cabinets are conducted through attached rubber gloves. When in use the cabinets are maintained under a negative pressure of 0.5 to 0.75 inches of water. The cabinet supply and exhaust air is filtered through single and double HEPA filters separately. The exhaust system for the cabinets may be a dedicated system or integrated with the general exhaust system.

Class III cabinets are generally designed as a system of interconnected cabinets which contain sufficient space for all research procedures. Refrigerators, incubators, centrifuges, animal cage housing and other equipment are housed in the cabinets so that the research can be performed without removing materials from the cabinet system. Double door autoclaves and chemical dunk tanks are installed as an integral part of the system to allow for the safe introduction and removal of supplies and equipment.

A BL4 laboratory may also have a suit area in which the operator is protected from the potentially contaminated environment by a one-piece positive pressure suit that is ventilated by a life support system.

Supplied air is HEPA filtered as it enters the suit. In such a facility the laboratory area becomes a primary barrier and the internal shell of the area is airtight. Entry to this area is through an air-lock fitted with airtight doors that are interlocked so that only one door can be opened during entry or exit procedures. A chemical shower is used to decontaminate the suit before removal. The exhaust air from this unit is filtered through two HEPA filters in series. The negative pressure within this area is greater than in any adjacent area. The suit's air supply is provided with alarms and emergency backup tank air. Emergency lighting and communications are provided.

For summary of general containment guidelines for BL4 facility see Table 9-1.

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TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS

Note: -- = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
A. APPROPRIATE FACILITY FOR LABORATORY FUNCTION OR ACTIVITY INVOLVING:					
1. Human and animal pathogens	Class 1 & Class 2 Agents	Class 1 & Class 2 Agents	Class 3 Agents	Class 3 Agents	Class 4 Agents
2. Oncogenic (cancer) viruses	Low Risk Viruses	Low Risk Viruses	Moderate Risk Viruses	Moderate Risk Viruses	High Risk Viruses
3. Chemical compounds	--	--	Carcino-gens Radioiso-topes	Carcino-gens Radioiso-topes	Carcino-gens Radioiso-topes
4. Organisms containing recombinant DNA and/or RNA molecules	BL1 & BL2 Classifi-cation	BL1 & BL2 Classifi-cation	BL3 Classifi-cation	BL3 Classifi-cation	BL4 Classifi-cation
B. LABORATORY PRACTICES AND TECHNIQUES:					
1. Access to lab limited or restricted	--	Rec	Req	Req	Req
2. No persons, animals, or plants not related to research project	--	Req	Req	Req	Req
3. Personnel entry/exit through clothing change and shower rooms	--	--	Req	Req	Req

TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS (continued)

Note: — = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
4. Materials, supplies, and equipment entry through double-doored autoclave, fumigation chamber, or airlock	--	--	Req	Req	Req
5. Work conducted in primary containment equipment	Open Bench Tops	Req	Req	Req	Req
6. Mechanical pipetting used	Req	Req	Req	Req	Req
7. Procedures to minimize aerosols	Req	Req	Req	Req	Req
8. When feasible, use alternatives instead of hypodermic needles and syringes	Rec	Req	Req	Req	Req
9. Laboratory clothing	Req	Req	Req	Req	Req
10. Gloves selected and used	--	Rec	Req	Req	Req
11. No eating, smoking, drinking, or applying cosmetics	Req	Req	Req	Req	Req
12. No contact lenses	Req	Req	Req	Req	Req
13. Hands washed before leaving lab	Req	Req	Req	Req	Req
14. Work surfaces decontaminated daily	Req	Req	Req	Req	Req

TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS (continued)

Note: — = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
15. All wastes from labs and animal rooms decontaminated or sterilized before disposal	Req	Req	Req	Req	Req
16. Lab clothing decontaminated before laundry	--	Req	Req	Req	Req
17. Animal cages autoclaved before cleaning	--	Req	Req	Req	Req
18. Biosafety manual prepared or adopted	--	Req	Req	Req	Req
19. Respiratory protection program	N/A	N/A	Rec	Rec	Req
20. Insect and rodent control program	Req	Req	Req	Req	Req
21. Appropriate cautionary signs	—	Req	Req	Req	Req
22. Medical surveillance and immunization	Req	Req	Req	Req	Req
23. Yearly certification of lab	--	—	Req	Req	Req
C. LABORATORY FACILITY:					
1. Separate building or isolated zone within a building	—	--	Req	Req	Req

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TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS (continued)

Note: -- = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
2. BSC or other appropriate personal protective or physical containment devices	N/A	Class I or II BSC	Class II or III BSC	Class II or III BSC	Class III or Class I or II BSC with ventilated suit
3. Fume hood	--	--	Req	Req	Req
4. Suit room	--	--	--	--	Req
5. Other primary containment equipment	N/A	N/A	Req	Req	Req
6. Steam and/or ethylene-oxide sterilizers:					
Available	Rec	Req	Req	Req	Req
Integral	--	--	Rec	Req	Req
Double-door	--	--	Req	Req	Req
7. Liquid effluent (bio-waste) sterilization system	--	--	Rec	Req	Req
8. Personnel change room	--	--	Rec	Req	Req
9. Shower available within facility	--	--	Req	Req	Req
10. Lab contiguous with shower	--	--	Rec	Req	Req
11. Emergency showers	Req	Req	Req	Req	Req
12. Eyewash stations	Req	Req	Req	Req	Req

9-28

TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS (continued)

Note: — = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
13. Handwashing facility:					
Available	Req	Req	Req	Req	Req
Foot, elbow, or automatically operated	Req	Req	Req	Req	Req
14. Work Surfaces:					
Bench Tops					
Impervious to water	Req	Req	Req	Req	Req
Resistant to acids, alkalis, organic solvents, and moderate heat	Req	Req	Req	Req	Req
Seamless	—	--	--	--	Req
15. Interior surfaces of walls, floors, and ceilings:					
Monolithic	--	--	Req	Req	Req
Resistant to liquids and chemicals	--	--	Req	Req	Req
All penetrations sealed or sealable	--	—	Req	Req	Req
Any drains in the floors contain traps filled with chemical disinfectant	--	--	Req	Req	Req

TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS (continued)

Note: — = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
16. Access doors:					
Closable	Req	Req	Req	Req	Req
Self-closing/ locking	--	--	Req	Req	Req
17. Windows:					
No windows	N/A	N/A	Rec	Rec	Rec
With windows:					
If openable, fitted with fly screens	Req	Req	N/A	N/A	N/A
Closed and sealed	N/A	N/A	Req	Req	Req
Safety glass	--	--	Req	Req	Req
18. Animal room:					
Cages solid-sided	—	—	Req	Req	Req
Cages ventilated or filtered	--	--	Req	Req	Req
Restraining devices	--	--	Req	Req	Req
19. Vacuum outlets protected by HEPA filters and liquid disinfectant traps	—	--	Req	Req	Req
20. Other liquid and gas services protected by backflow preventers	—	--	Req	Req	Req

TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS (continued)

Note: — = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
21. Sewer and other vent lines protected by HEPA filters	—	—	Req	Req	Req
22. Ventilation:					
Facility					
Individual supply and exhaust air system	—	—	Req	Req	Req
Single pass (no recirculation)	Req	Req	Req	Req	Req
Directional air flow	—	—	Req	Req	Req
Pressure gradient	—	—	Req	Req	Req
Supply/exhaust interlock (lead exhaust)	Req	Req	Req	Req	Req
HEPA filtered supply	—	—	—	—	Req
HEPA filtered exhaust	—	—	Req	Req	Req
Containment Equipment					
HEPA filtered supply					
Class III BSC	N/A	N/A	Req	Req	Req
Suit area	N/A	N/A	Req	Req	Req

TABLE 9-1 - GENERAL CONTAINMENT GUIDELINES FOR RENOVATION OR CONSTRUCTION OF RESEARCH FACILITIES FOR WORK WITH HAZARDOUS MATERIALS (continued)

Note: -- = No Recommendation; No Requirement
N/A = Not Applicable
Rec = Recommended
Req = Required

Facility Type	Basic Microbiological Laboratory		Containment Facility		Maximum Containment Facility
Biosafety Levels	BL1	BL2	BL3	BL3 Ag	BL4
HEPA filtered exhaust					
Class I and II BSC	N/A	N/A	Req	Req	Req
Class III BSC with two sets of HEPA in series	N/A	N/A	Req	Req	Req
Suite area with two sets of HEPA in series	N/A	N/A	N/A	N/A	Req
23. Leak tightness testing and certification of critical components of the biological containment system prior to final acceptance of the completed work					
Biological safety cabinets	N/A	N/A	Req	Req	Req
HEPA filter assemblies	N/A	N/A	Req	Req	Req
Containment room	N/A	N/A	Req	Req	Req
Welded ductwork	N/A	N/A	Req	Req	Req

PART 5. SPECIAL DESIGN ISSUES

9.5.1 **General.** This part provides the special design issues that must be addressed in the design of a biological containment facility.

9.5.2 **Architectural elements.**

a. **Facility layout.**

1. A containment facility shall be separated by controlled access zones from areas open to the public and other laboratory personnel who do not work within the containment facility.

2. Each laboratory module of the containment facility shall be capable of accommodating a biological safety cabinet.

3. Adequate means of egress shall be provided from all laboratories without breeching containment or promoting cross contamination. Air locks, when required, shall be provided and located at transitional points between the zones through which personnel and/or materials must pass.

4. A foot, elbow, or automatically operated hand washing facility shall be provided near the exit area of each primary laboratory module.

b. **Room envelope and interior finishes.**

1. The design shall include construction materials and finishes that are compatible with research materials and decontamination methods.

2. The surface finishes of walls, floors, and ceilings shall be resistant to liquid penetration and be readily cleanable. The recommended floor surface is a monolithic-type covering that is free of seams or cracks.

3. The openings in walls, floors, and ceilings through which utility services and air ducts penetrate shall be sealed to permit space decontamination. These openings can be effectively sealed by the application of a liquid silicone plastic. All seals shall be installed on both sides of penetration openings, at a location readily accessible for inspection and maintenance.

4. The Laboratory shall be provided with adequate casework. Work surfaces shall be impervious to water and resistant to acids, alkalis, organic solvents, and moderate heat.

9.5.3 Mechanical elements.

a. **Airflow patterns.**

1. Separate air handling systems shall be provided for non-contaminated and contaminated areas for isolation purposes.

2. **No recirculation.** In contaminated spaces each air handling system shall be designed to utilize 100 percent outside air for heating, ventilation and air conditioning.

3. **Direction of flow.** The established direction of air flow shall be from less contaminated to more contaminated spaces and shall remain unchanged under all conditions. Airflow direction within the laboratory room shall be from the entrance door toward the rear of the room.

4. **Constant flow.** The air flow rate to each room shall remain reasonably constant. Air flow rates shall not be varied for purposes of temperature controls. The air changes shall be 8 to 10 (laboratories), 6 to 8 (offices), and 10 to 12 (animal rooms).

5. **Negative pressures.** A series of differential pressures of 0.05 in wg shall be employed to control the direction of movement of airborne particles. Air pressure shall be more negative in the zones that possess higher potentials for contamination with infectious agents than in those possessing a lower contamination potential.

b. **Supply and exhaust systems.**

1. **Location.** Active components in HVAC systems shall be located outside the containment envelope for ease of maintenance. Space must be provided surrounding mechanical equipment for future preventive maintenance actions.

2. **Capacity.** The capacity of the exhaust system, fan, motor and drive shall be 15 percent greater than the capacity of the supply air system.

3. **Gas-tight ductwork.** Exhaust ductwork carrying contaminated air shall be made pressure tight (as determined by the specified acceptance testing of ductwork at +4 inches wg) including all joints and seams.

4. **Air filtration.** The exhaust air from biological safety cabinets, other containment equipment, and laboratory space shall be filtered through high-efficiency particulate air (HEPA) filters before discharging to outside. Specify the 99.97 percent efficiency filters listed by the National Sanitation Foundation (NSF). Coarse filters shall be provided for treatment of air supplied to the facility in order to increase the lifetime of the HEPA filters.

5. **HEPA filter design and location.** Supply/exhaust HEPA filters shall be located as close as possible to containment source and containment envelope to reduce length of gas-tight ductwork. The HEPA filter housing shall be designed to allow physical isolation from ductwork using low leakage certifiable dampers or any other approved mechanical means to allow in-place decontamination before filters are removed and to facilitate certification testing after they are replaced. Design shall allow ease of access for a human of standard proportions. Access ports must be functional, properly located and sealable.

6. **Redundant fans.** Redundant fans shall be considered in the design of supply and exhaust air ventilation system.

7. **Outside air intake.** In the design of outside air intakes, consideration must be given to their continuous operation in adverse weather. Rain and snow must be baffled out of the air stream so it will not wet or clog the filter. Outside air intakes shall be separated as far as practicable from the points of exhaust. In selecting locations, consideration shall be given to prevailing wind patterns of the geographical area. A supply HEPA filter is required in certain supply ventilation systems in addition to the course filters.

8. **Material of construction.** All materials for ductwork, filter housings, exhaust fans, including protective coatings, shall be selected to withstand corrosive and erosive conditions characteristic of the exhaust gases that will be handled.

c. **Services.**

1. Service piping shall be installed with sloping lines. Use backflow preventers to isolate branch water lines. Piping should never be mounted in direct contact with a wall to avoid crevices that might permit buildup of contamination, and to promote ease of painting and cleaning.

2. Compressed air/instrument air shall be protected by small, in-line HEPAs commercially available.

3. **Floor drains.** All floor drains will have a minimum of 5-inch deep trap which are connected directly to the liquid waste decontamination system. All drain cleanout plugs must be located within the containment zone.

4. **Vacuum system.** If there is a central vacuum system, it shall not serve areas outside of the facility. In-line HEPA filters shall be placed as near as practicable to each use point or service cock. Filters shall be installed to permit in-place decontamination and replacement. Vacuum receiver tanks must be fitted with a single HEPA filter and decontamination ports for the tank itself and the mechanical pump.

5. **Other utilities.** Other liquid (water) and gas services to the facility shall be protected by devices that prevent backflow.

6. **Hand washing facility.** A foot, elbow, or automatically operated hand washing facility shall be provided near the exit area of each primary laboratory module. The sink shall be constructed of materials such as stainless steel or epoxy-coated resins which are resistant to possible chemical and other spillage. The drain shall have a removable, cleanable strainer to prevent solid materials from getting into the drainage system.

9.5.4 Electrical elements.

a. **Distribution panel.** Separate power and lighting distribution panels shall be provided for contaminated and non-contaminated areas.

b. **Conduit and wiring.** Conduit in contaminated areas shall be run exposed. Conduit shall be of rigid steel, hot-dipped galvanized type. To prevent the spread of infectious agents through inside openings of the conduit, conduit passing through the wall and/or floor from a contaminated area to a non-contaminated area, or between areas of different levels of contamination, shall be sealed using Type EYS sealing fittings. All seals shall be installed at a location readily accessible for inspection and maintenance.

c. **Lighting fixture installation.** Fluorescent lighting fixtures shall be installed flush against the ceiling to prevent dust accumulation.

d. **Emergency power.** A standby generator shall be provided to be automatically switched on in case of power outage within the building. To serve critical components only; e.g., repositories, animal rooms, emergency lighting.

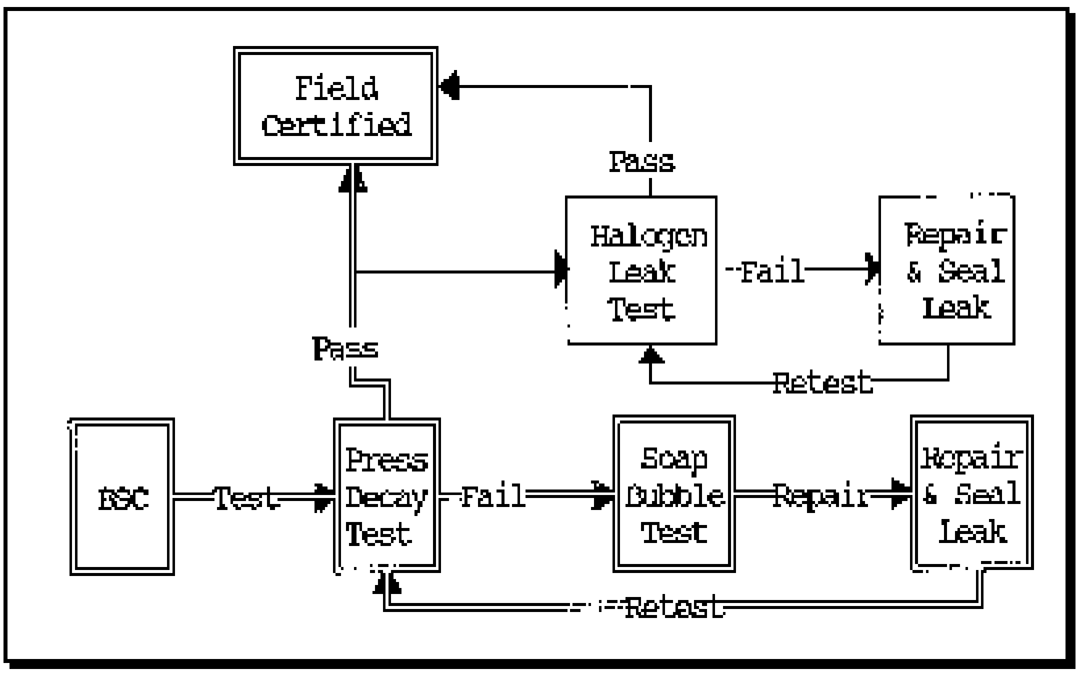
e. **Interlocks.** The air locks, pass boxes and double-door sterilizers shall be protected with interlocks so that both doors cannot be opened simultaneously. The supply and exhaust fans shall be interlocked to prevent pressurization in the event of exhaust fan failure.

PART 6. TESTING AND CERTIFICATION REQUIREMENTS FOR CRITICAL COMPONENTS OF BIOLOGICAL CONTAINMENT SYSTEM

9.6.1 **General.** This part provides the requirements for testing and certification that must be conducted at the factory and/or field to verify the containment integrity of the critical components of biological containment system.

9.6.2 **Testing and certification of biological safety cabinets.** (Per NSF Standard No. 49 procedures).

a. **Process diagram.**



NOTE: Double lines indicate process for testing and certification of BSC plenums. Single lines indicate **additional** test process required for all BSC with biologically contaminated plenums under positive pressure to the room.

b. **Test No. 1 (BSC)-Pressure decay/soap bubble test.**

The pressure decay/soap bubble test shall be performed on exterior surfaces of all BSC plenums to determine if welds, gaskets, and plenum penetrations or seals are free of leaks.

1. **Apparatus** (BSC).

- A source of soap solution (e.g., liquid detergent with a low surface tension, or commercial test solution such as "leak-tek", "search", or "snoop").
- A source of air pressure (portable tank or compressed air source).
- A calibrated and scaled manometer (preferably inclined), pressure gauge, or pressure transducer.
- Soft bristle brush or liquid squeeze bottle which can be used to apply soap solution to duct or plenum seams, welds, gaskets, or other locations which can be a point source of air leakage.
- Sealing plates to form isolation barriers.

2. **Procedure** (BSC).

- Prepare the cabinet as a closed system; i.e., seal the front window and exhaust port.
- Remove decorative panels where necessary to expose plenums to be tested.
- Attach a manometer, pressure gauge, or pressure transducer system to the test area to indicate the interior pressure.
- Pressurize the cabinet with air to a reading of 2 in. wg and hold for 30 minutes. A leakage of 10 percent of the original pressure is allowable.
- If the cabinet leak exceeds 10 percent, spray or brush the liquid leak detector along all welds, gaskets, penetrations, or seals on exterior surfaces of cabinet plenums. Leaks will be indicated by bubbles. Leaks will occur that blow the detection fluid from the hole without forming bubbles, and may be detected by slight feel of airflow or sound.
- Repair/seal all identified leaks and repeat test until the acceptance criteria specified below is satisfied.

3. **Acceptance criteria.** (BSC - Pres.Decay/Soap Bubble Test)

All welds, gaskets, penetrations, or seals on exterior surfaces of air plenums shall hold pressure within 10 percent for 30 minutes or shall be free of soap bubbles at 2 in. wg.

c. **Test No. 2 (BSC) - Halogen leak test.**

The halogen leak test shall be performed in addition to pressure decay/soap bubble test if BSC has biologically contaminated air plenums under positive pressure relative to the room. It will determine if exterior joints made by welding, gasketing, or sealing with sealants are free of leaks that might release potentially hazardous materials into the atmosphere.

NOTE: "Helium" shall be used as the test gas, however, using "freon" is acceptable provided halogenated compounds are not outlawed in the time lapse before testing commences.

1. **Apparatus.**

- A source of soap solution (e.g., liquid detergent with a low surface tension, or commercial test solution such as "leak-tek", "search", or "snoop").

- A source of air pressure (portable tank or compressed air source).

- A calibrated and scaled manometer (preferably inclined), pressure gauge, or pressure transducer.

- Soft bristle brush or squeeze bottle which can be used to apply soap solution to duct or plenum seams, welds, gaskets, or other locations which can be a point source of air leakage.

- Sealing plates to form isolation barriers.

- An industrial type halogen leak detector capable of detecting a halide leak of 1 x 10^{-7} cc/sec. The halogen leak detector shall be calibrated in accordance with the manufacturer's instructions using a calibrated leak standard.

- A source of halide gas (Freon-Dichlorodifluoromethane).

2. **Procedure** (Halogen Leak Test).

- The room where testing will be performed shall be free of halogenated compounds, and air movements kept to a minimum. No smoking should take place in the test area.

- Prepare the cabinet as a closed system; i.e., seal the front window and exhaust port.

- Remove decorative panels where necessary to expose plenums to be tested.

- Attach a manometer, pressure gauge, or pressure transducer system to the test area to indicate the interior pressure.

- Pressurize the cabinet with air to 2 in. wg, if the cabinet holds this pressure without loss for 30 minutes, release pressure. If the cabinet does not hold this pressure, examine for gross leaks with soap solution, repair/seal all leaks and repeat test.

- Pressurize the cabinet to 2 in. wg with halide gas (Freon - Dichlorodifluoromethane).

- Turn on cabinet blower for 30 seconds to circulate gas.

- Adjust the halogen leak detector to a sensitivity setting of 5×10^{-7} cc/sec, in accordance with the manufacturer's instructions.

- Move the detector probe over seams, joints, utility penetrations, panel gaskets, and other areas of possible leakage. Move the detector probe over the surface at a rate of approximately 1 inch per second, keeping the probe 1/4 to 1/2 inch away from the surface.

- Identify all points of leakage which exceed the leak rate of 5×10^{-5} cc/sec.

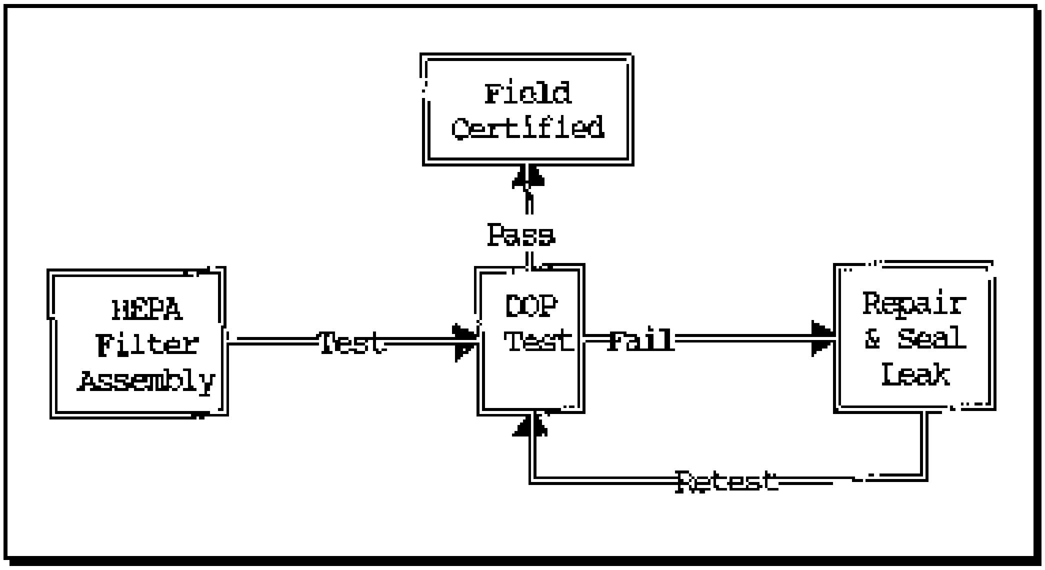
- Repair/seal all identified leaks and repeat test until the acceptance criteria specified below is satisfied.

3. **Acceptance Criteria** (BSC-Halogen Leak Test).

   Absolute leakage from any point in the cabinet shall not exceed a leak rate of 5×10^{-5} cc/sec when the air inside the cabinet at 1 atmosphere is pressurized with 100 percent Freon R-12 to 2 in. wg. The halide detector must be set to respond to a lower detectable concentration of 5×10^{-7} cc/sec to compensate for the dilution of halide gas.

9.6.3 TESTING AND CERTIFICATION OF HEPA FILTER ASSEMBLY.

a. **Process Diagram.**



b. **Test No. 1 (HEPA) - DOP test.**

The Dioctylphthalate (DOP) test shall be performed to verify that the in-place HEPA filters do not contain pinhole leaks in the filter media, the bond between the filter media and the filter frame, and in and around the filter frame gasket and filter supports.

1. **Apparatus.**

- An aerosol photometer with either linear or logarithmic scale. The photometer shall have a threshold sensitivity of at least 1 x 10^{-3} micrograms per liter for 0.3 micrometer diameter DOP particles and a capacity for measuring an 80-120 micrograms per liter concentration. The air sampling rate shall be at least 1 cfm.

- A DOP generator of the Laskin nozzle(s) type. An aerosol of DOP particles shall be created by flowing air through liquid DOP. The compressed air supplied to the generator should be adjusted to a pressure of 20 psi, measured at the entrance of the nozzle, downstream of all restrictions. The nozzles shall be covered with DOP to a depth not to exceed 1 inch.

2. **Procedure (DOP).**

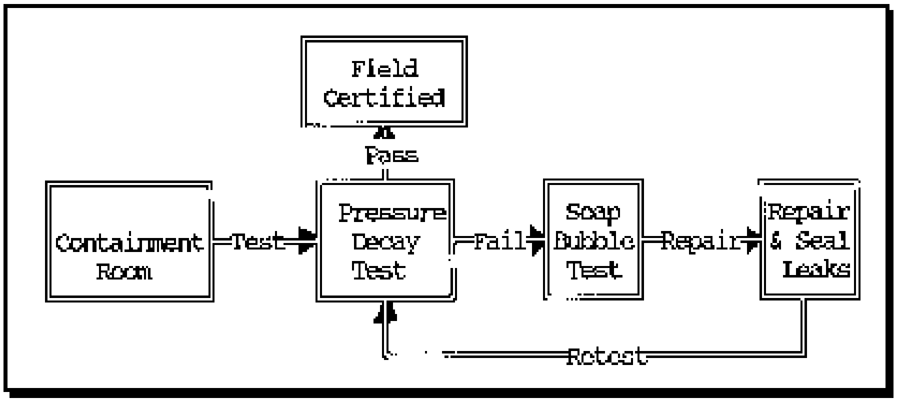
- Isolate and seal the filter plenum.
- Place the generator so the DOP aerosol is introduced into the filter plenum, upstream of the HEPA filter.
- Turn on the photometer and calibrate in accordance with the manufacturer's instructions.
- Measure DOP concentration upstream of the HEPA filter.
  - For linear readout photometers (graduated 0-100), adjust the instrument to read 100 percent while using at least one Laskin type nozzle per 500 cfm airflow or increments thereof.
  - For logarithmic readout photometers, adjust the upstream concentration to 1 x 10^4 above the concentration necessary for one scale division (using the instrument calibration curve).
- With the nozzle of the probe not more than 1 inch from the surface, scan the downstream side of the HEPA filters and the perimeter of each filter pack by passing the photometer probe in slightly overlapping strokes over the entire surface of the HEPA filter. Scan the entire periphery of the filter and the junction between filter and filter mounting frame. Scanning shall be done at a traverse rate of not more than 2 inches/second.
- Identify all points of leakage which exceed 0.01 percent of DOP penetration.
- Repair/seal all identified leaks and repeat test until the acceptance criteria specified below is satisfied.

3. **Acceptance Criteria (HEPA DOP Test).**

Dioctylphthalate (DOP) penetration shall not exceed 0.01 percent at any point measured by a linear or logarithmic photometer.

9.6.4 TESTING AND CERTIFICATION OF A CONTAINMENT ROOM. (Penetrations, walls, ceiling and floor surfaces in containment buildings).

a. **Process diagram.**



b. **TEST NO. 1 (CONTAINMENT ROOM) - PRESSURE DECAY/SOAP BUBBLE TEST.**

This test shall be performed to determine if the walls, ceiling, and floor surfaces of a containment building or room can serve as a barrier to prevent environmental release of hazardous material or leakage between adjacent areas.

NOTE: This test can be conducted under vacuum or pressure as described below:

1. **Apparatus (Pressure Decay/Soap Bubble).**

- Sealing materials (wood, metal, or plastic plates; pressure sensitive tape, sheet of plastic, rubber stoppers) to form isolation barriers within the test zone.

- Source of air pressure (portable tank or compressed air).

- A calibrated and scaled manometer (preferably inclined), pressure gauge, or pressure transducer.

- A source of soap solution (e.g., liquid detergent with a low surface tension, or commercial test solution such as "leak-tek", "search", or "snoop").

- Soft bristle brush or squeezable bottle which can be used to apply soap solution to the surface.

2. <u>Procedure (Pressure Decay/Soap Bubble)</u>.

- Seal all external openings. Sealing materials shall cover and seal only the opening so as not to cover the adjacent permanent seals, which would not permit testing these seals.

- Pressurize room or building with air to 2 in. wg.

- Observe and record test pressure and decay rate.

- Survey all joints, corners and sealed penetration for audible leaks. Mark each leak and repair after shutting down the source of air pressure. Do not apply a retest until sealant or other repairs have set.

- Further leakage can be found using the soap bubble test.

- Apply soap or commercial detector solution on all joints, corners and sealed penetrations or other locations which can be a point source of air leakage.

- Establish 2 inches **negative** pressure in the room and observe for bubble formation. Leaks will be indicated by bubbles. Leaks will occur that blow the detection fluid from the hole without forming bubbles, and may be detected by slight feel of airflow or sound.

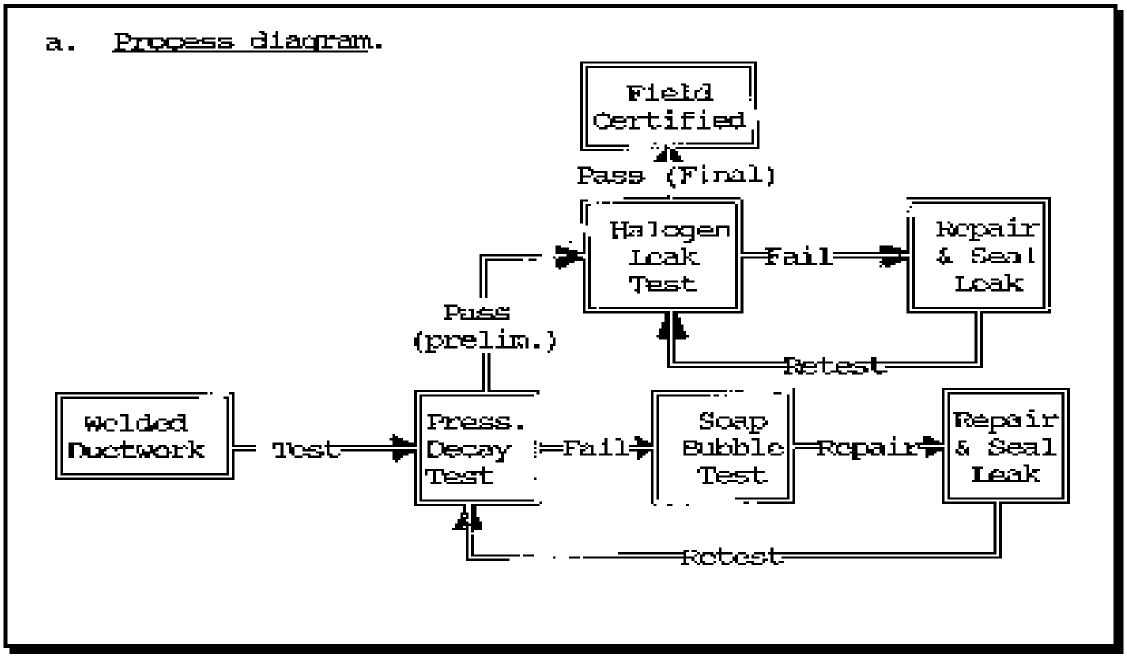
- Mark each leak and shut down the source of air pressure.

- Repair/seal all identified leaks and repeat test until the acceptance criteria specified below is satisfied. Do not apply a retest until sealant or other repairs have set.

3. **Acceptance Criteria (Containment Room-Pres.Decay/Soap Bubble Test).**

The air leak rate shall not exceed 7 percent per minute (logarithmic of pressure against time) over a 20 minute period at 2 in. wg. Normally, this air leak rate is equivalent to 0.05 in. wg pressure loss in 1 minute at 2 in. wgp.

9.6.5 TESTING AND CERTIFICATION OF WELDED DUCTWORK.



a. **Process diagram.**

b. **TEST NO. 1 (WELDED DUCTWORK) - PRESSURE DECAY/SOAP BUBBLE TEST.**

This test shall be performed as a **preliminary** test to locate leaks in the system so they can be corrected prior to proceeding with the more stringent acceptance criteria of the **halogen leak test (final)**, and thereby avoiding the contamination of the surrounding background with the halogenated compounds that might interfere with the halogen compound detection instrument during final testing.

1. **Apparatus (Pressure Decay/Soap Bubble).**

- A source of soap solution (e.g., liquid detergent with a low surface tension, or commercial test solution such as "leak-tek", "search", or "snoop").
- A source of air pressure (portable tank or compressed air source).
- A calibrated and scaled manometer (preferably inclined), pressure gauge, or pressure transducer.

- Soft bristle brush or liquid squeezable bottle which can be used to apply soap solution to duct or plenum seams, welds, gaskets, or other locations which can be a point source of air leakage.

- Sealing plates to form isolation barriers.

2. **Procedure (Pressure Decay/Soap Bubble).**

- Expose all exterior surfaces of ducts and plenums. All joints must be readily accessible to perform this test.

- Isolate and seal the system to be tested.

- Attach a manometer, pressure gauge, or pressure transducer system to the test area to indicate the interior pressure.

- Pressurize ducts and plenums with air to a reading of 4 in. wg. Allow sufficient time (20 to 30 minutes when room temperature is about 77°F) for the temperature inside the duct/plenum to equilibrate within 2°F of the outside surroundings before proceeding. This temperature gradient shall be reported in the final report.

- Observe and record the test pressure and decay rate.

- Apply soap or commercial detector solution on all joints, gaskets, penetrations, or seals on exterior surfaces of ducts and plenums, and observe for bubble formation. Leaks will be indicated by bubbles. Leaks will occur that blow the detection fluid from the hole without forming bubbles, and may be detected by slight feel of airflow or sound.

- Mark each leak and shut down the source of air pressure.

- Repair/seal all identified leaks and repeat test until the acceptance criteria specified below is satisfied. Do not apply a retest until sealant or other repairs have set.

3. **Acceptance criteria (Welded Ductwork).** (Pres.Decay/ Soap Bubble Test)

All welds, gaskets, penetrations, or seals on exterior surfaces of ducts and plenums shall hold air pressure for 20 minutes and shall be free of soap bubbles at 4 in. wg.

c. **TEST NO. 2 (WELDED DUCTWORK) - HALOGEN LEAK TEST.**

The halogen leak test shall be performed on all welded ductwork and plenums as a final test to determine if exterior joints made by welding, gasketing, or sealing with sealants are free of leaks that might release potentially hazardous materials into the atmosphere. Access doors (for HEPA filters or dampers) in the ductwork or plenums located within the established containment boundaries shall be tested and certified as part of the ductwork system.

NOTE: "Helium" shall be used as the test gas, however using "freon" is acceptable provided halogenated compounds are not outlawed in the time lapse before testing commences.

1. **Apparatus (Halogen Leak Test).**

- An industrial type halogen leak detector capable of detecting a halogen leak of 1×10^{-7} cc/sec (e.g., General Electric Ferrett, G.E. Catalog No. 50-420-810 HFJK or approved equal).

- The halogen leak detector shall be calibrated in accordance with the manufacturer's instruction using a calibrated leak standard (General Electric LS20, Catalog No. 50-420-701 AAAMI (0-10 x 10^{-7} cc/sec) or equal.

- A source of halogen gas (Freon - Dichlorodifluoromethane).

- Respirator equipped with a cartridge for organic vapor removal to be worn by person generating gas on high pressure side.

- Two-way communication system.

- A calibrated and scaled manometer (preferably inclined), pressure gauge, or pressure transducer.

2. **Procedure (Halogen Leak Test).**

- Remove halogenated compounds from the test area.

- Calibrate the leak detector according to the manufacturer's instructions. Adjust the leak standard to indicate a leak rate of 1×10^{-7} cc/sec.

- Prior to testing, perform a background scan of the area to insure the atmosphere is free of halogenated compounds.

- Pressurize all sealed ducts and plenums to 4 inches wg with a Freon/air mixture (1-Freon and 9-air by volume mixture).

- Move detector probe over seams, joints, gaskets, and other areas of possible leakage at a rate of approximately 1 inch/sec. Keep detector probe approximately 1/4 to 1/2 inch away from the surface.

- Identify all points of halogen leakage which exceed 1 X 10^{-5} cc/sec.

- Repair/seal all identified leaks and repeat test until the acceptable criteria specified below is satisfied. Do not apply a retest until sealant or other repairs have set.

3. **Acceptance Criteria (Welded Ductwork - Halogen Leak Test).**

   Leak rate shall not exceed 1 x 10^{-5} cc/sec.

PART 7. BID DOCUMENT PREPARATION

9.7.1 **Scope.** This part provides special requirements relative to the preparation and development of construction drawings and specifications for a biological containment facility.

9.7.2 **Demolition and temporary work.** For renovation of existing containment facility, the overall renovation work shall be carefully examined for their impact on adjacent unrenovated facilities. The construction drawings and specifications shall address the following.

a. Decontamination requirements and debris disposal guidelines during demolition.

b. Temporary conditions required by demolition and phasing (dust partitions, security partitions, temporary AHU requirements, etc.).

9.7.3 **Containment boundaries.** The contract documents shall include floor plans showing the containment boundaries. The drawings shall indicate the location of barriers which are not to have penetrations, and locations of barriers which may have penetrations.

9.7.4 **Penetration details.** The contract documents shall include special details for sealing all penetrations through containment barriers. Special details shall be developed for every penetration including structural, ductwork, all types of pipe, conduit, wire, gang boxes, telephone/data cabling, control tubing, etc.

9.7.5 **Sealing existing and new openings.** The contract documents shall detail the required method of sealing existing and new openings. This shall include any surface materials as necessary to provide a monolithic surface of containments to meet the appropriate leak-tightness tests.

9.7.6 **Pressure levels and directional airflow.** The contract documents shall include containment floor plans and schematics showing pressure levels and relationships, airflow direction, and CFM capacities. One common base atmospheric point should be used for all systems. Consider effects of dynamic actions (elevators, doors, hood changes) on pressure relationships and system response.

9.7.7 **Name Brand Specification.** In a biocontainment construction work, it may be necessary to specify materials or products which are not commonly used and may be hard to find. In such cases it is permissible to specify the source of the uncommon product by stating the supplier's name and address, and trade name of the product subject to the following conditions:

a. When more than one source of the uncommon product is found, both/all must be listed.

b. The project specification shall contain the following statement: "The use of a trade name and supplier's name and address in the specification is to indicate a possible source of the product. The same type of product from other sources shall not be excluded provided they possess like physical characteristics, color, and texture. If the product is from a foreign supplier, it shall be subject to the Buy America Act".

9.7.8 **Testing Requirements.** All testing and certification requirements of the contractor shall be specified. An itemized list of equipment to be tested and types of testing required must be included. For containment the requirements for testing of ductwork and rooms must be specified. The following equipment and systems should be, at a minimum, tested and validated.

a. Leak tightness of supply and exhaust ductwork at pressures specified.

b. Factory-testing of HEPA filters and other critical components.

c. Field-testing of HEPA filters after installation.

d. Sound levels in laboratories and animal rooms.

e. Differential pressures and/or directional airflows between adjacent areas.

f. Field testing of biological safety cabinets.

9.7.9 **Project close-out requirements**. The contract documents shall clearly spell out project close-out requirements. Issues to be addressed in specifications shall include inspection punch list, acceptance criteria, warranties, certifications, testing/start-up of equipment, validation of systems operation, containment testing, etc.

PART 8. GLOSSARY OF TERMS

Absolute Filter - See HEPA filter.

Aerosol - A suspension of very fine particles of solid or liquid in air or gas.

Air Lock - A section of corridor isolated by doors, used to separate areas with different levels of biohazard and at different air pressures, which permits passage of personnel and/or equipment normally without airflow. Under special conditions, air locks may be pressurized by the addition of a HEPA filtered air supply. When air locks are treatable with paraformaldehyde, the doors shall be gastight and an exhaust duct can be run to the nearest autoclave exhaust hood or to the atmosphere to evacuate the paraformaldehyde from the air lock. A manual damper is provided outside the air lock for use when evacuating the air lock. See also "UV Air Lock."

Airtight or Airtight - See "Gastight."

Aircraft Grade Compound - A sealing compound used for sealing biological safety cabinets and for other caulking uses where a gastight seal is required.

Animal Cage - Container, generally metal, but may be of plastic, either autoclavable or disposable, designed for permanent housing of (usually individual) animals; may be individually ventilated or open to surrounding atmosphere. Used in both non-biohazard or biohazard areas.

Animal Cage Rack - Stack of steel shelves, generally movable, used to hold animal cages.

Area - Generally used in this chapter to designate a portion of a building at a given level of biohazard as set off from adjoining portions of different biohazard levels. Used somewhat interchangeably with "space."

Attic - An important utility service area for the laboratories; contains much service equipment including the central ventilation equipment.

Autoclave - A chamber used for heat sterilization of materials and equipment by direct exposure to steam under pressure. An autoclave that has been modified to permit optional use of a gaseous decontaminates instead of steam is generally referred to as a "gas sterilizer" in this chapter. See also "Gas Sterilizer."

Back Flow Preventer - A manufactured piping device of the type that has two independently acting check valves and one spring-loaded, diaphragm-activated differential pressure relief valve. It is installed in a water supply line to prevent reversal of water flow in case the supply pressure falls below the downstream pressure. See also "Vacuum Breaker."

BAS - Building Automation System - A computerized system with a multitude of points for measuring (and in some cases controlling) flow rates, temperatures, pressures, etc. Can be used for fire protection, security requirements, and HVAC controls (including pumps, blowers, compressors, etc.).

Biohazard - Any material, equipment, person, or animal in a biohazard area is considered to be contaminated with infectious microorganisms.

Biohazard Area - A building area with definite boundaries where hazardous biological work is being carried out, separated from non-biohazard and other biohazard areas by suitable barriers.

Biohazard Change Room - Dressing room for removal of laboratory-type clothing before entering clean change room, through a mandatory shower, to don street clothing.

Biohazard Service - A service or utility, such as water or vacuum, which serves a biohazard area and is therefore segregated from similar services to non-biohazard areas even though the service itself is non-biohazard.

Biohazard Suite - A group of biohazard laboratory rooms that is isolated from non-hazard areas and other areas by change rooms and UV air locks.

Biological - An infectious microorganism or toxin that is being handled in the course of research, development, or testing.

Biological Safety Cabinet, Class I - See "Class I Biological Safety Cabinet."

Biological Safety Cabinet, Class II - See "Class III Biological Safety Cabinet."

Biologically Separated - Term applied to areas that are isolated from each other by air locks, change rooms, and shower.

Blowcase - See "Waste Collection Treatment Unit."

Cabinet, Class I - See "Class I Biological Safety Cabinet."

Cabinet, Class II - See Class II Biological Safety Cabinet."

Cabinet, Class III - See "Class III Biological Safety Cabinet."

Cabinet Array - A number of Class III biological safety cabinets joined together. An array may be divided into two or more cabinet systems by gastight doors or fixed partitions.

Cabinet System - A number of Class II biological safety cabinets joined to provide a single space with a single inlet and exhaust for ventilation.

Cage - See "Animal Cage."

Cage Rack - See "Animal Cage Rack."

Caulking - Such as silicone sealant; See also "Aircraft Grade Compound" and "Construction Grade Compound."

Change Room(s) - Grouping of dressing rooms, locker rooms, lavatories, air locks, and showers to provide personnel access to and egress from biohazard areas without allowing escape of any biohazard; See also "Clean Change Room" and "Biohazard Change Room."

Class I Biological Safety Cabinet - A prefabricated, ventilated enclosure that provides a physical barrier between a worker and a hazardous operation. It may be used with an open front (or open glove ports or with attached gloves) and a high rate of ventilation away from the operator, like a fume hood, or with a closed front and attached rubber gloves. In the latter use, protection depends upon a negative pressure maintained within the cabinet. The ventilated air exhausts through a HEPA filter.

Class II Biological Safety Cabinet - A prefabricated ventilated enclosure for personnel, product, and environmental protection having an open front with inward airflow for personnel protection, HEPA filtered laminar airflow for product protection, and HEPA filtered exhaust air for environmental protection. Different models are available; See text for description of types.

Class III Biological Safety Cabinet - A prefabricated, gastight, and ventilated enclosure maintained at negative pressure in which some BL3 or all BL4 work is done using attached rubber gloves with a single HEPA filter on the inlet and a double HEPA filter on the exhaust.

Clean - Has been commonly used in the past to mean "free of harmful microorganisms" but has been replaced by "non-biohazard" (except in the term "clean change room") to avoid possible confusion with the special meaning (of being dust free) given to "clean room" or "clean area" in the aerospace industry. When used in this chapter, "clean" has its ordinary meaning of "unsoiled" without reference to microorganisms.

Clean Change Room - Dressing room for removal of street clothes and donning laboratory clothing before entering biohazard change room through an air lock. (Clean is an exception to the use of non-biohazard.)

Clean Room - See "Clean."

Construction Grade Compound - A sealing compound used for all exterior and interior caulking, except where aircraft grade compound is required (see "Aircraft Grade Compound").

Decontamination - The word "decontamination" is a provincial term used to describe all sterilizing, disinfecting, sanitizing, and washing procedures.

Decontamination Shower - See "disinfectant shower."

Demand Factor - Percent of total connected load (for utilities).

Diaphragm Valve - Widely used in biohazard service because of zero leakage at the stem (also referred to as "Saunders Valve").

Disinfectant Shower - Unit at exit from ventilated suit area in which suit is externally decontaminated for a specified time, by a mist or spray of disinfectant such as peracetic acid, before being removed.

Exfiltration - (Ventilation Term) ductless flow of air from a space to an adjoining space at lower pressure.

Freon-tight - See "Gastight."

Gas Sterilizer - An autoclave that has been designed to permit optional use of a gaseous decontaminates instead of steam for sterilizing materials. Gas sterilizer can be purchased specifically for GAS USE ONLY.

Gastight - Free from leakage when subjected to the standard halogen leak test.

Germfree - Free of all microbial life detectable by examination.

Glove Box - See "Class III Biological Safety Cabinet."

Gravity Exhaust - (Ventilation term) discharge of air, resulting only from pressure differential, from a ventilated room to the outdoors through an exhaust duct.

High Efficiency Particulate Air (HEPA) Filter - A throwaway, extended/pleated medium, dry-type filter with: (1) rigid casing enclosing the full depth of the pleats, (2) minimum particulate removal of 99.97 percent for thermally generated monodisperse dioctylphthalate (DOP) smoke particles with a diameter of 0.3 um, and (3) maximum pressure drop of 1.0 in wg (25.4 mm) when clean and operated at rated airflow capacity. Other types of HEPA filters are available; e.g., ceramic sinterred metal, etc., for pipeline filtering and other uses.

Hood Area - See "Ventilated Suit Area."

Infectious Microorganisms - As used in this manual, the term is restricted to microorganisms infectious for man or domestic animals.

Infiltration - (Ventilation Term) ductless flow of air into a space from an adjoining space at higher pressure.

Laminar Flow - Straight-line, eddy-free flow, applied specifically to airflow as a means of controlling spread of aerosols in the ventilation of biohazard work areas. Employed in clean rooms, down flow rooms, and crossflow rooms in the aerospace and pharmaceutical industries.

Magnahelix Gauge - Instrument used to measure differential pressure; i.e., between Class II safety cabinet and the room and/or between laboratory room and hallway.

Mask - See "Respirator."

Mask Air - Piped supply of conditioned air for ventilated personnel suits and hoods. See also "Ventilated Suit."

Non-Biohazard Area - An area with definite boundaries designed to be free of harmful microorganisms. See also "Clean."

Microorganisms - In this chapter, when not qualified, refers to infectious microorganisms.

Non-Biohazard Change Room - See "Clean Change Room."

Pass Box - A double-doored chamber arranged to permit transfer of material and equipment between two confined spaces of different biohazard levels such as a safety cabinet and the room, two safety cabinet systems, a room and a corridor, etc. May employ steam, gas, U.V. radiation, or liquid as the decontamination agent. See also "Autoclave" and U.V. Pass Box".

Pasteurization - Heat treatment of a liquid under conditions of time and temperature (usually 200 degrees F) that will substantially reduce, but not completely eliminate, the population of microorganisms.

Peracetic Acid - One of the compounds used for disinfecting suits.

Peracetic Shower - See "Disinfectant Shower."

Personal Assistance Alarm - An emergency manual alarm activated by pull station (usually located near an exit) and/or emergency shower flow switch.

Pipe Line Filter - A HEPA filter designed to withstand sterilization.

Plenum - When not otherwise specified, refers to filter chamber or filter housing in a central ventilation system.

Post-Wide Alarm System - A system to detect abnormal operation of any critical or important mechanical device or system. Warning is given at a building annunciator panel and at a central annunciator panel that is manned 24 hours a day.

Pressure-tight - Free from leakage in a soap test at +4 inches wg pressure.

Receiving Room, Biohazard - An area for holding biohazard equipment and materials until they can be sterilized and passed through double-door autoclaves or gas sterilizers that open into the non-biohazard receiving room.

Receiving Room, Non-biohazard - A service room generally at the rear of the building that is maintained as a non-biohazard area. Supplies delivered to the building are placed in the receiving room before transfer through a U.V. air lock to the biohazard receiving room.

Refuse Incinerator - A fuel-fired furnace for the combustion of organic wastes, in which all gases will have reached a minimum temperature of 1400 degrees F before discharge.

Respirator - A conventional device covering the nose and mouth, which provides a filter for inspirated air.

Rodent-Proof - Incorporating prescribed structural and architectural features in building design that prevent access or harboring of rodents and other vermin.

Safety Cabinet, Class I - See "Class I Biological Safety Cabinet."

Safety Cabinet, Class II - See "Class II Biological Safety Cabinet."

Safety Cabinet, Class III - See "Class III Biological Safety Cabinet."

Safety Shower/Eye Wash Station - A combination emergency plumbing fixture with drench-type shower and two eye/face wash heads. Installed in every chemical, battery, and radiological use area and as otherwise required.

Sealant - See "Aircraft Grade Compound" and "Construction Grade Compound."

Service Piping - Piping other than waste piping or process piping.

Shower - See "Change Room", "Disinfectant Shower", and "Safety Shower/Eye Wash Station."

Speaking Diaphragm - Plastic sheet installed in wall, door, or window to permit voice communication through barrier between areas of different biohazard levels.

Steam Seal - Section of piping between two valves, kept filled with steam when not in use, to isolate a vessel or line from another vessel or line from waste drain lines, etc.

Sterilization - Complete destruction or inactivation of microorganisms.

Sterilizer - See "Autoclave."

Suit Area - See "Ventilated Suit Area."

Suite - See "Biohazard Suite."

System - See "Cabinet System."

Toxin - A metabolic product of microorganisms poisonous to man or animals.

U.V. Air Lock - An air lock located between areas of different levels of biohazard and air pressure. For the transfer of personnel and/or equipment. The interior is a curtain of UV. Clothing work in the biohazard laboratory is discarded into the laundry bag in the biohazard change room.

U.V. Pass Box - A pass box in which U.V. radiation is used for surface decontamination of material or equipment. See "Pass Box."

Vacuum Breaker - A device that is installed in a line or tank, where the breaker is not subjected to a downstream back-pressure, to prevent reversal of flow in case of accidental occurrence of an upstream suction.

Ventilated Cages - See "Animal Cage."

Ventilated Hood - Hood covering entire head, pressurized with conditioned air by same hose system serving ventilated suits.

Ventilated Suit - Pressurized outer garment (including head, hands, and feet), supplied by hose with conditioned air, and worn in areas of high risk from infectious aerosols such as some animal rooms.

Ventilated Suit Area - Area of high hazard in which workers are protected by ventilated suits and which is separated from adjoining area of lower biohazard risk by various barriers including change rooms provided with disinfectant showers.

Vermin Proof - See "Rodent Proof."

Viewing Panel - Fixed window suitably sealed into an interior wall or door between two areas of different biohazard levels.

Viewing Window - See "Viewing Panel."

Waste Collection Tank - See "Waste Collection Treatment Unit."

Waste Collection Treatment Unit - A waste collection and treatment unit, generally serving one building, consisting of a tank in which the biohazard liquid waste is collected, sterilized or pasteurized by steam either continuously or batch-wise, and discharged to the main municipal-type sewer system. Commonly called "blowcase."

Waste Piping - Unless specified as "sanitary" or "storm water", refers to piping handling biohazard waste (biohazard sewer).

CHAPTER 10. ANIMAL RESEARCH AND CARE FACILITIES

PART 1. GENERAL

10.1.1 Scope: This chapter provides general guidance in the planning and design of animal research and care facilities.

10.1.2 ARS Policy:

a. ARS animal research and care facilities shall be designed in accordance with the Animal Welfare Act (9 CFR Parts 1, 2, and 3) and the NIH Guide for the Care and Use of Laboratory Animals, 1985 (or later revisions as available) and other applicable Federal laws, guidelines and policies.

b. The design of facilities for animal research and care shall provide for living conditions of animals appropriate for their species and contribute to their health and comfort. Design must ensure that all research animals are protected to prevent transmission of diseases among animals and to and from humans.

PART 2. ANIMAL WELFARE CONSIDERATIONS

10.2.1 General: The caging or housing system shall be designed carefully to facilitate animal well-being and meet research requirements.

a. The housing system shall:

1) Provide space that is adequate as defined by law and guidelines (See 10.1.2a), permits freedom of movement and normal posture adjustments, and has a resting place appropriate to the species, and exercise (if required by law for the species).

2) Provide a comfortable environment.

3) Provide an escape-proof enclosure that confines animals safely.

4) Provide easy access to food and water.

5) Provide adequate ventilation.

6) Meet the biological needs of the animals; e.g., maintenance of body temperature, urination,

defecation, and if appropriate, reproduction.

7) Keep the animals dry and clean, consistent with special requirements.

8) Avoid unnecessary physical restraints; and protect the animals from known hazards.

b. **The Caging Systems** shall be designed to comply with the Animal Welfare Act (9 CFR Parts 2 and 3) and the NIH Guide for the Care and Use of Laboratory Animals, 1985 (or later revisions). They shall be constructed of sturdy, durable materials and designed to minimize cross- infection between adjoining units. To simplify servicing and sanitation, cages shall have smooth, impervious surfaces that neither attract nor retain dirt and a minimum number of ledges, angles, and corners in which dirt or water can accumulate. The design shall allow inspection of cage occupants without disturbing them. Feeding and watering devices shall be easily accessible for filling, changing, and servicing.

10.2.2 Housing Facilities - General: Housing facility shall mean any land, premises, shed, barn, building, trailer, or other structure or area housing or intended to house animals.

a. **Structural Strength:** Indoor and outdoor housing facilities shall be structurally sound and shall be maintained in good repair, to protect the animals from injury, to contain the animals, and to restrict the entrance of other animals and to restrict the entrance of unauthorized humans.

b. **Water and Electric Power:** Reliable and adequate electric power and adequate potable water shall be available. A separate emergency generator shall power all environmental controls that are required for systems essential for the animal's health (e.g., heating, cooling, air supply).

c. **Storage:** Supplies of dry food and bedding shall be stored in special rooms in animal facilities which adequately protect such supplies against moisture accumulation and infestation or contamination with vermin.

d. **Waste Disposal:** In animal facilities, a separate exit (not used for arrival of clean supplies) shall be provided for the removal and disposal of animal and food wastes. Provisions shall be made for the removal and disposal of animal and food wastes, bedding, and dead animals and debris. Disposal facilities shall be so provided and operated as to minimize vermin infestation, odors, and disease hazards.

e. **Washrooms and Sinks:** Facilities such as washrooms, sinks, or basins, showers and toilets, shall be provided to maintain cleanliness among animal caretakers.

10.2.3 Housing Facilities - Indoors:

a. **Heating:** Indoor housing facilities for species shall be sufficiently heated when necessary to protect animals from cold, and to provide for their comfort. The temperature ranges are listed in the Animal Welfare Act and/or NIH Guide for the Care of Laboratory Animals. The ambient temperature shall not be allowed to fall below 50°F for animals not acclimated to lower temperatures.

b. **Ventilation:** Indoor housing facilities shall be adequately ventilated to provide for the health and comfort of the animals at all times. Facilities for small animals shall not have windows in the core animal housing rooms: They shall have air intake and exhaust vents and air conditioning organized so that air circulates through the entire room (without dead spots) and there shall be at least 15 exchanges of new (not recirculated) air per hour. Moisture content shall be in the range appropriate for the species. Air conditioning shall be available at all times to maintain the temperature within the range appropriate for the species. The entire ventilation system shall also be served by an emergency generator that assures proper ventilation to the animals during power problems.

c. **Lighting:** Indoor housing facilities for animals shall have ample, good quality artificial light in the appropriate spectrum and daily light cycle required by the species. Room lighting shall provide uniformly distributed illumination of sufficient light intensity to permit routine inspection and cleaning during the entire working period. Animals that require choice of dark or light during the "day" period shall be provided with the means (through cage design) to make this choice.

d. **Interior Surfaces:** The interior building surfaces of indoor housing facilities shall be constructed and maintained so they are substantially impervious to moisture and coated with mold-resistant paint whenever possible. Floors should be seamless (to minimize microbial contamination and facilitate cleaning).

e. **Drainage:** If closed drainage systems are used, they shall be equipped with traps and so installed as to prevent any backup of sewage onto the floor of the room.

10.2.4 Housing Facilities - Outdoors:

a. **Shelter From Sunlight:** When sunlight is likely to cause overheating or discomfort, sufficient shade shall be provided to allow animals kept outdoors to protect themselves from the direct rays of the sun.

b. **Shelter From Rain or Snow:** Animals kept outdoors shall be provided with access to allow them to remain dry during rain or snow.

c. **Shelter From Cold Weather:** Shelter shall be provided for animals kept outdoors when the atmospheric temperature falls below 50ºF. Sufficient clean bedding material or other means of protection from the weather elements shall be provided when the ambient temperature falls below that temperature to which the animal is acclimated.

d. **Drainage:** A suitable method shall be provided to rapidly eliminate excess water.

PART 3. DESIGN FEATURES

10.3.1 Physical Relationship of Animal Facilities To Laboratories: Locate animal housing areas adjacent to or near laboratories, but separated from them by barriers such as entry locks, corridors, or floors.

10.3.2 Functional Areas : The size and nature of a facility will determine whether areas for separate service functions are possible or necessary.

a. Sufficient animal area is required to:

1) Ensure separation of species or isolation of individual research projects when necessary;

2) Receive, quarantine, and isolate animals; and

3) Provide for animal housing.

b. Generally, facilities shall make provisions for the following service functions:

1) Specialized laboratories or individual areas contiguous with or near animal housing areas for such activities as surgery, intensive care, necropsy, radiography, preparation of special diets, experimental manipulation, treatment, and diagnostic laboratory procedures.

2) Containment facilities or equipment, if hazardous, biological, physical, or chemical agents are to be used.

3) Receiving and storage areas for food, bedding, pharmaceuticals and biologics, and supplies.

4) Space for the administration, supervision, and direction of the facility.

5) Showers, sinks, lockers, and toilets for personnel.

6) A room or suite of rooms for washing and sterilizing equipment and supplies, and, depending on the volume of work, machines for washing cages, bottles, glassware racks, and waste cans; a utility sink; an autoclave for equipment, food, and bedding; and separate areas for holding soiled and clean equipment.

7) An area for repairing cages and equipment is desirable, but may not be practical in the same building if the animal facility is small.

8) An area to store waste prior to incineration or removal.

10.3.3 Noise Control:

a. Noise control is an important consideration in facility design. Equipment noises and low pitch rumbles can lead to animal stress and human caretaker stress. Major equipment such as used for heating and cooling (including emergency generators) should be separated from animal housing rooms and offices for caretakers by partitions designed to minimize transfer of stressful sounds and vibrations.

b. Within animal facilities, noisy activities, such as cage washing and refuse disposal, shall be carried out in special rooms separated from the for animal housing rooms by a combination of (1) placement of clean storage rooms between those in which noisy activities take place and animal housing rooms, and (2) surrounding the rooms in which the noisy activities take place with extra thick walls.

c. Noisy animals, such as dogs and nonhuman primates, shall be housed away from rodents, rabbits, and cats.

10.3.4 Water Supply:

a. Animals shall be provided with continuous access to fresh, potable, uncontaminated drinking water, according to their particular requirements. Watering devices, such as drinking tubes and automatic waterers shall be provided.

10.3.5 Materials and Finishes: Building materials shall be selected to facilitate efficient and hygienic operation of animal facilities.

a. Durable, moistureproof, fire resistant, seamless materials are most desirable for interior surfaces.

b. Paints and glazes, in addition to being highly resistant to the effects of chemical solvents, cleaning agents, and scrubbing, shall be highly resistant to the effects of high pressure sprays and impact. They shall be nontoxic if used on surfaces that come into direct contact with animals.

10.3.6 Floors, Walls, and Ceilings:

a. Animal laboratories shall have impervious surfaces and structural joints that are vermin-proof and easily cleaned and decontaminated.

b. The walls and floors shall be monolithic and made of washable and chemically resistant plastic, baked enamel, epoxy, or polyester coatings.

c. The monolithic floor covering shall be carried up 8 inches of the wall to prevent accumulations of dirt and wastes in the corners.

d. Corridors subject to heavy traffic from transportation of cage racks and hand trucks handling feed and wastes shall be constructed of materials resistant to wear and frequent washing with detergents and disinfectants.

e. Walls in corridors and animal holding rooms shall be provided with buffer strips as necessary to prevent cage racks and hand carts from colliding with the walls and thereby gouging the surface and rupturing the monolithic coatings. Exposed wall corners shall be reinforced with steel or other durable material.

f. Suspended ceilings shall not be used.

10.3.7 Doors and Windows:

a. Exterior windows and skylights are not recommended in animal rooms because they can contribute to unacceptable variations in environmental characteristics such as temperature.

b. Animal room doors shall be at least 42 inches wide and 84 inches high to facilitate passage of racks and equipment.

c. Metal or metal-covered doors with viewing windows shall be provided in animal rooms.

d. Doors and frames shall be completely sealed to prevent the the entrance or harboring of vermin. Self-sealing sweep strips are desirable.

e. Doors shall be equipped with locks and kickplates and be self-closing. Recessed or shielded handles and locks are recommended.

10.3.8 Heating, Ventilating and Air-Conditioning:

a. Animal laboratories require rigid control of temperature, humidity, and air movement in animal rooms at all times to provide optimal conditions for the health and growth of the species housed therein. The animal rooms shall be capable of an adjustable temperature range between 65 and 84°F and a relative humidity range between 30 and 70 percent. All animal rooms must have at least 15 fresh (not recirculated) air changes/hour.

b. Room air in animal facilities shall not be recirculated.

c. Air pressure in animal rooms and surgical suites shall be higher than that of corridors to minimize contamination of animal rooms. Air pressure in dirty equipment washing rooms shall be lower than that in corridors to minimize spread of contamination and noxious odors. Air pressure in rooms that are used to store clean equipment and materials shall be higher than that in the washing rooms.

10.3.9 Illumination:

a. Lighting shall be uniformly diffused throughout the animal facilities and provide sufficient illumination to aid in maintaining good housekeeping practices, adequate inspection of animals, safe working conditions for personnel, and the well being of the animals. Over illumination is stressful for some animals (e.g., albinos): These animals should have shaded shelters provided in their cages.

b. Provision shall be made for the use of variable-intensity controls to ensure light intensities consistent with needs of animals and personnel working in animal rooms and energy conservation.

c. A time-controlled lighting system shall be used when required to provide a regular diurnal lighting cycle.

CHAPTER 11. GREENHOUSE DESIGN GUIDE

PART 1. GENERAL

11.1.1 Scope. ARS uses standardized designs for its research greenhouses. This chapter provides the design guidelines as described in the ARS Greenhouse Design Standard (GDS). The chapter does not include requirements for containment greenhouses at the biosafety levels BL2, 3, or 4. All greenhouse space specified for research with hazardous microorganisms or exotic plant pathogens must comply with the systems and items identified in Chapter 9. The difference is the handling and containment of plant pathogens versus epizoonotic or zoonotic livestock diseases. Examination of the research mission will clarify the necessity for contained greenhouse space at the BL2 or 3 containment levels. ARS does not have plans to construct BL4 greenhouse space, scientists who identify this need will coordinate their research with the research leader of the Foreign Disease-Weed Science Research Laboratory at Fort Detrick, Frederick, Maryland.

11.1.2 An Overview of the ARS Greenhouse Design Standard (GDS):

a. The ARS Greenhouse Design Standard (GDS) comprises the **design guidelines, specifications, and an expert system.** These GDS components were developed to:

1) Provide a data base on and a consistent analytical approach to greenhouse design;

2) Limit design variability and therefore reduce costs and time associated with greenhouse design;

3) Increase control of the quality of the final product; and

4) Provide a built environment that both responds to current research needs and can accommodate changes required by future research objectives.

b. **The GDS design guidelines** (provided hereafter) make available to the A-E firm a vocabulary of pre-researched, pre-approved, and limited types of systems, components, and operational procedures, as well as information on designing with this vocabulary.

c. **The specifications section** of the GDS describe in detail the materials and fabrication techniques that are acceptable to ARS. A copy of the specifications section may be obtained through the EPM.

d. **The expert system** assists the ARS scientists in formulating building programs that are appropriate for particular research, economic, and climatic conditions encountered at ARS centers across the U.S. The expert system accesses a knowledge base of architecture, engineering, and heuristic rules and uses a multiple-attribute analytical technique to weigh competing objectives in the decision making process. First the expert system translates the research needs of the scientists into functional requirements for the greenhouse. Based on those functional requirements, recommendations are made for the use of specific greenhouse systems, subsystems, and components and for implementation of specific operation strategies.

The GDS expert system consists of the system software and the knowledge base. The system is designed to run on an IBM personal computer, XT, AT and compatibles, with a hard disk, and a PC-DOS/MS-DOS version 2.0 or later operating system. Therefore a knowledge of MS-DOS operating system commands is necessary to use the system. The following is a description of the expert system components and how they may be obtained.

System Software

The software is the LEVEL5 Run-Only (R/O) expert system software, Version 1.3. It may be procured for $131.25 + shipping through:

Information Builders, Inc.
503 5th Avenue
Indialantic, Florida 32903
Attn: Will Eaton
Telephone: (800) 444-4303
FAX: (407) 727-7615

The GSA contract number is GSOOK89AGS6435PSO1.

The level5 R/O software installation instructions are included in the reference manual delivered with the software. Contact Information Builders, Inc. on (212) 736-6130 if technical assistance is required.

Knowledge Base

The knowledge base is captured on three 5 and 1/4 inch floppy discs. These will be provided upon request, at no cost, by either the Head, Facilities Engineering Eastern Branch (FEEB), or the Head, Facilities Engineering Western Branch (FEWB), of the Facilities Construction Management Division.

The knowledge base is installed using MS-DOS operating system commands. A videotape describing the GDS expert system is available for loan from either FEEB or FEWB.

11.1.3 Abbreviations And Symbols.

Acronyms	Name
ACI	American Concrete Institute
AIA	American Institute of Architects
AISC	American Institute for Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASAE	American Society of Agricultural Engineers
ASTM	American Society for Testing and Materials
BOCA	Building Officials and Code Administrators International, Inc.
CABO	Council of American Building Officials
FGMA	Flat Glass Marketing Association
ICBO	International Conference of Building Officials
NFPA	National Fire Protection Association
SBCCI	Southern Building Code Congress International, Inc.
SIGMA	Sealed Insulating Glass Manufacturers Association

11.1.4 Reference Standards.

ACI (318-83), "Building Code Requirements for Reinforced Concrete", 1st printing November 1983, Detroit, Michigan.

AIA, Robert T. Packard, ed., Ramsey/Sleeper "Architectural Graphics Standards", seventh edition, John Wiley and Sons, New York, 1981.

AISC (1980), "Manual of Steel Construction," Eighth Edition, Chicago, Ill.

AISI (1980), "Specification for the Design of Cold-Formed Steel Structural Members", Washington, D.C.

The Aluminum Association, Inc., "Specifications for Aluminum Structures", Fourth Edition, April 1982, Washington, D.C.

ANSI (1986), "American National Standard Buildings and Facilities Providing Accessibility and Usability for Physically Handicapped People", New York, NY.

BOCA (1987), "Basic Building Code."

CABO (1986), Model Energy Code.

ICBO (1985), Uniform Building Code.

NFPA (1987), National Electrical Code.

SBCCI (1986), Standard Building Code.

SIGMA (1986), "Voluntary Guidelines for Sloped Glazing of Organically Sealed Insulating Glass Units", Document A-2801-77 (86) Chicago, Ill.

11.1.5 Regulatory Requirements.

a. The greenhouse shall conform to all requirements of the local building code or to the applicable current edition of the following model building codes, whichever is more stringent:

The ICBO Uniform Building Code
The SBCCI Standard Building Code
The BOCA Basic Building Code

Refer to the map in Figure 11-1 to determine the governing model building code for the greenhouse location.

b. The following subject areas are addressed by the codes and are applicable to greenhouses either by specific reference or by generic requirement.

Use-group classification	Fire resistance
Construction type	Fire protection
Design loads	Plumbing systems
Means of egress	HVAC systems
Light-transmitting plastic	Energy conservation
Area and height limits	Skylights/glass panels
Sprinkler/alarm systems	Light and wiring
Building envelope requirement	

APPROXIMATE AREAS OF CODE INFLUENCE

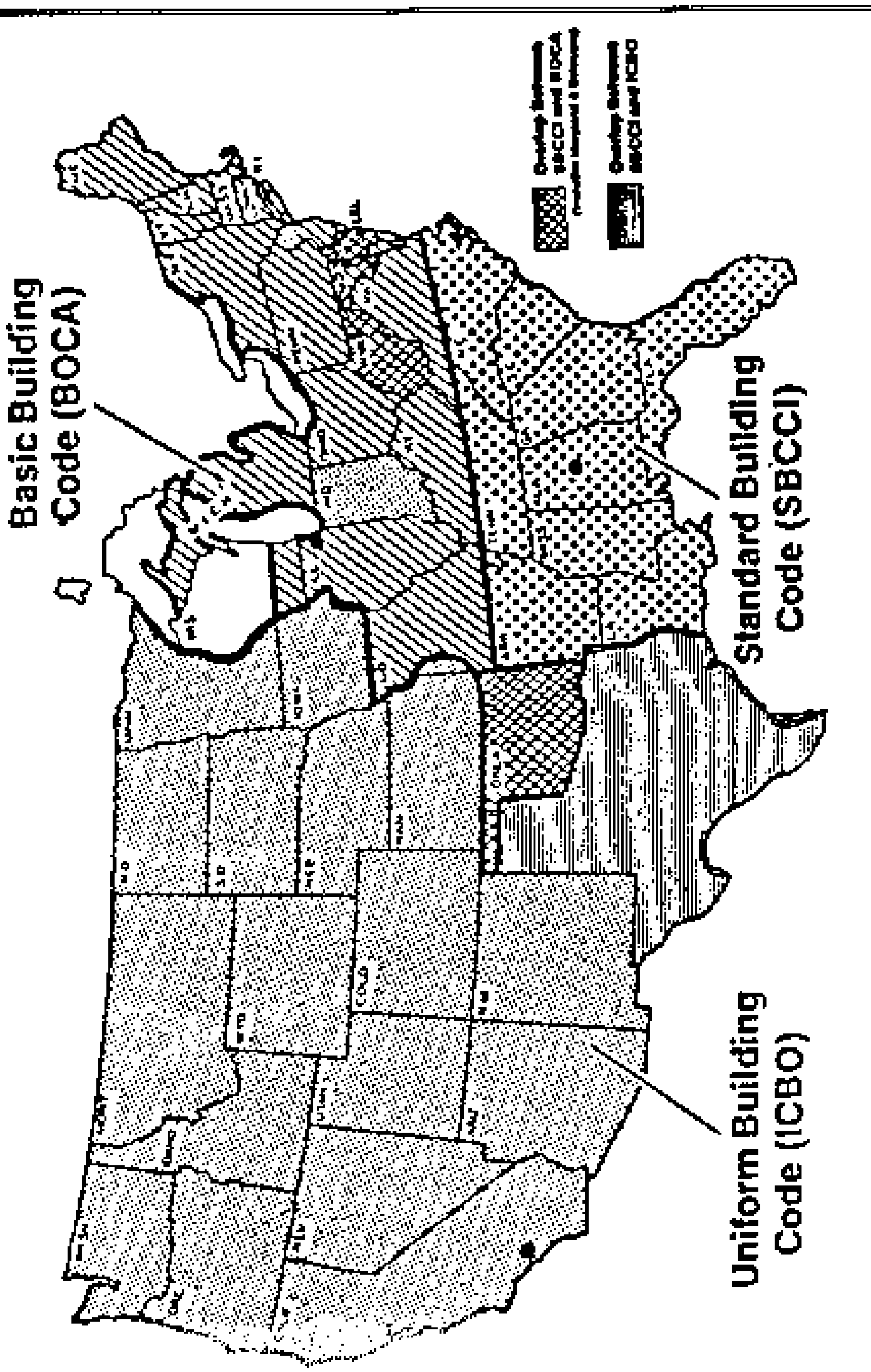


FIGURE 11-1

Source: Council of American Building Officials

11.1.6 USDA-ARS Requirements.

a. **Licensed Professional Requirement:** The completed set of working drawings shall be reviewed by a licensed architect or engineer prior to submittal to the government. The foundation drawings shall bear the seal and signature of an architect or engineer licensed to practice in the jurisdiction within which the construction will be undertaken.

b. **Greenhouse Definitions:**

1) **Level 1 Greenhouses -** These greenhouses are used primarily to prolong the growing season into the spring and fall, as well as through the summer, by means of augmented heating, and/or to extend the photo period on a daily basis with augmented lighting. The environmental control should be relatively simple. The plants can withstand fairly large variations in temperature and humidity. The construction materials used in enclosures shall be of a quality and have characteristics to withstand exposure to the elements for a minimum of five years.

2) **Level 2 Greenhouses -** These greenhouses are usable throughout the year. The ability to extend the photoperiod shall be provided. Environmental condition ranges shall be permitted, but the heating and cooling system shall be sized to protect the plants and to avoid relocation during the heating and cooling season extremes. The construction materials used in enclosures shall be of a quality and have characteristics to withstand exposure to the elements for a minimum of fifteen years, except for acrylic and polycarbonate glazing, which shall withstand exposure to the elements for a minimum of ten years. This requirement does not apply to shading and movable insulation devices. The control systems shall maintain specified environmental conditions to the maximum that the conditioning system capacities will provide, as well as maintaining control of the photo-period lighting. The plants housed in middle-level control greenhouses will be somewhat hardy in nature to withstand environmental condition swings.

3) **Level 3 Greenhouses -** These greenhouses are usable throughout the year. The mechanical heating, ventilation, and cooling systems shall be designed to fully augment the natural means to maintain specified environmental conditions. The lighting system shall also be designed to extend the photoperiod throughout the year in accordance with the plant research requirements. The control system shall operate the mechanical systems to maintain the environmental conditions within specified limits. The construction materials used in enclosures shall be of quality and have characteristics to withstand exposure to the elements for a minimum of twenty-five years, except for acrylic and polycarbonate glazing, which shall withstand exposure to the elements for a minimum of ten years. This requirement does not apply to shading and movable insulation devices.

PART 2. SITE WORK

11.2.1 General.

All site design shall be performed based on detailed investigation of existing conditions.

11.2.2 Surface Water Drainage.

a. Surface drainage patterns shall be investigated for each site condition. The amount of water, direction, blockages, undrained depressions and areas of continuing erosion shall all be considered.

b. All surfaces on a greenhouse site shall be sloped for drainage. Water shall flow as a result of gravity and always be drained away from the greenhouse structure. Large amounts of water shall not be drained across circulation paths. Slopes for surface drainage shall be:

   Land adjacent to buildings - 2% min. - 10% max.
   Swales - 2% min. - 10% max.
   Open Land - 1/2% min.
   Streets - 1/2% min.
   Planted Areas - 1% min - 25% max.
   Large Paved Areas - 1% min - 5% max.

c. The ground directly adjacent to the base of the greenhouse shall be sloped away. If necessary, swales shall be built around the greenhouse to direct surface water away.

11.2.3 Location and Orientation.

a. Research greenhouses typically have rectangular, oblong plans. The orientation of the long axis of the plan may have a considerable impact on the amount of natural light received by plants, and on the amount of heating and cooling energy required.

   In winter, the sun is relatively low and completes an apparent movement of less than 180 degrees from sunrise to sunset. As a result, most direct sunlight is captured through South-oriented vertical glazing.

   In summer the sun is relatively high and completes an apparent movement of more than 180 degrees from sunrise to sunset. Most direct sunlight is received through roof glazings. East and West vertical surfaces receive more solar exposure in summer than South vertical surfaces.

b. Because of the above considerations, greenhouses with the long axis oriented in a general East-West direction (i.e., greenhouses with Southern exposure) tend to: (1) receive more winter light and winter solar heat; (2) overheat less in summer. Furthermore, in Northern locations, the North greenhouse wall may be built opaque and insulated, thereby decreasing heating expenditures. This is because no direct light is captured through the North wall during winter, and negligible direct light is captured during summer.

c. However, Southern exposure need not be sought rigidly, since there are other factors, listed below, which may reduce its desirability:

1) **Latitude:** Southern latitudes provide more direct light in winter than Northern latitudes for East and West vertical glazing. Therefore, the heating penalty for orienting the long axis of the greenhouse in a North-South direction is decreased. Furthermore, in Southern locations which experience significant heating demand (such as locations with large daily temperatures swings above and below 70 degrees F), it may be advantageous to build the North gable opaque and insulated.

2) **Site conditions:** Site shape, slope and/or adjacency to other buildings may make Southern exposure impossible or prohibitively expensive.

3) **Plan shape:** For greenhouses approaching a square, the orientation becomes of little relevance.

4) **Width:** Even if the greenhouse plan is elongated, a wide greenhouse will have its radiation gains predominantly through the roof, rendering the orientation of the vertical surfaces less important.

5) **Artificial lighting:** Some research greenhouses rely heavily on artificial lighting. Orientation becomes less relevant in this case.

d. **Southern Exposure:** A greenhouse is defined as having Southern exposure when its long axis is located on an East-West direction, plus or minus 15 degrees. Building sites for greenhouses shall preferably have an open Southern exposure. Table 11-1 shall be used to locate the position of the greenhouse in relation with any adjacent obstruction situated within an AZ angle to the East of South or an AZ angle to the West of South, (see Figures 11-2 and 11-3). Any obstruction located outside this angle East or West of South shall be at a distance at least equal to its height. To determine how far the greenhouse shall be located from an obstruction, use Table 11-1.

Tables 11-2, 11-3, and 11-4 indicate the required spacing of adjacent, detached greenhouses of equal height and width to avoid shading on the North house.

Table 11-5 indicates the required spacing of prototype D, attached greenhouse (refer to Section 11.3.1 of this design guide to identify prototype D plans).

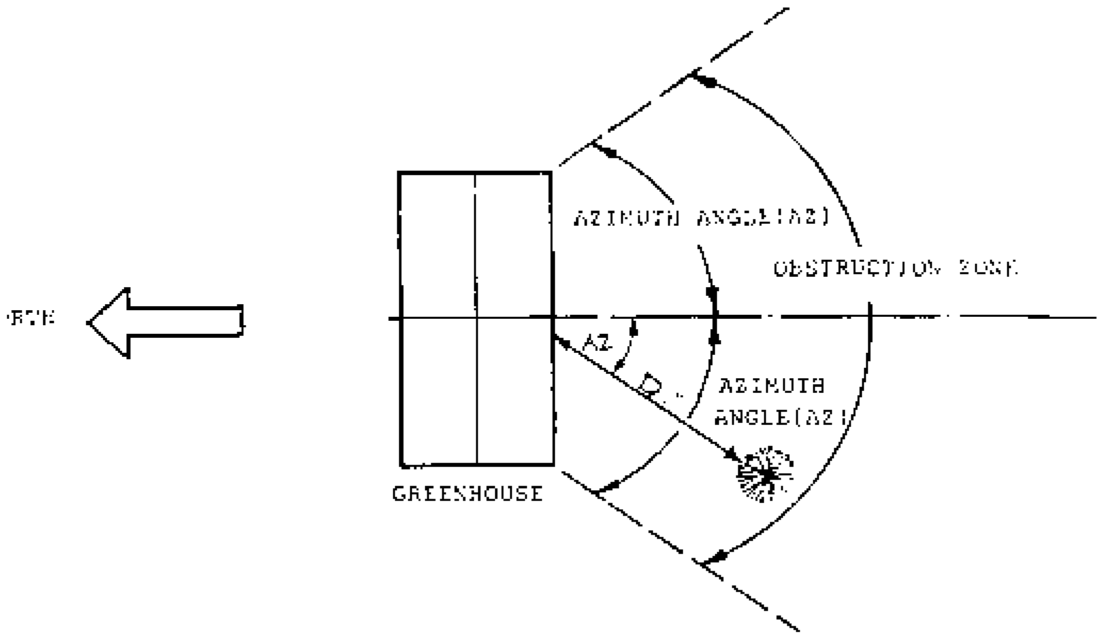


FIGURE 11-2

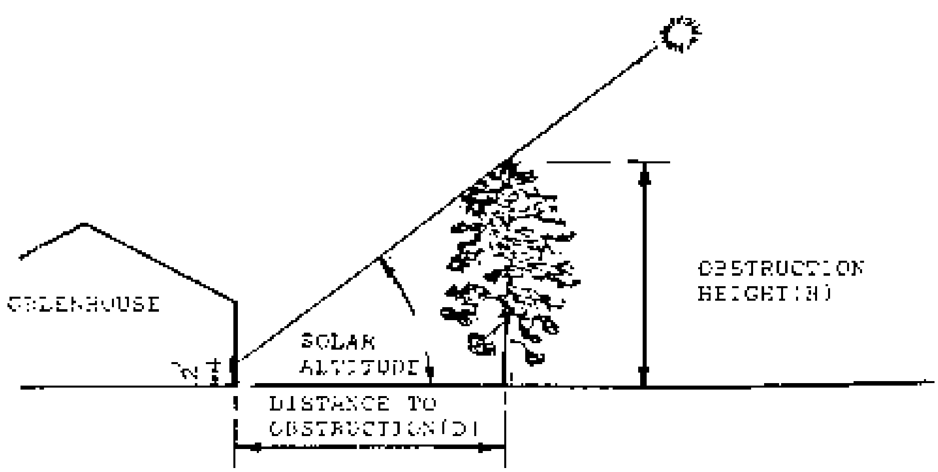


FIGURE 11-3

TABLE 11-1. Azimuth Angle From South And Distance-to-Height Ratios To Calculate The Minimum Distance Of Greenhouse From Obstruction

LATITUDE	AZIMUTH	DISTANCE = a x (Height)-b (feet)
16	57	1.7(H) - 3.3
24	46	2.1(H) - 4.1
32	44	2.7(H) - 5.5
40	42	4.0(H) - 8.0
48	41	7.1(H) - 14.2
56	27	8.1(H) - 16.3

TABLE 11-2: Minimum Spacing of Adjacent Detached 18 Foot Wide Greenhouses

LATITUDE	AZIMUTH	9' EAVE HT (feet)	11' EAVE HT (feet)
16	57	12	15
24	46	15	19
32	44	23	28
40	42	37	45
48	41	73	87
56	27	85	100

TABLE 11-3: Minimum Spacing of Adjacent Detached 25 Foot Wide Greenhouses

LATITUDE	9' EAVE HT (feet)	11' EAVE HT (feet)
16	12	15
24	15	19
32	24	29
40	41	49
48	82	96
56	95	112

TABLE 11-4 Minimum Spacing of Adjacent Detached 32 Foot Wide Greenhouses

LATITUDE	9' EAVE HT (feet)	11' EAVE HT (feet)
16	12	15
24	15	19
32	25	31
40	44	52

48	91	105
56	106	122

TABLE 11-5: MINIMUM CORRIDOR LENGTH (FEET) OF PROTOTYPE D HOUSES

North Latitude	18' Wide Houses		25' Wide Houses		32' Wide Houses	
	9' Eave Height	11'Eave Height	9'Eave Height	11' Eave Height	9'Eave Height	11' Eave Height
16	12	20	20	20	20	20
24	20	20	20	24	24	24
32	24	30	30	30	30	36
40	36	N/A	N/A	N/A	N/A	N/A

11.2.4 Windbreakers.

Protection from snow and wind storms, when such conditions exist, shall be provided alongside the greenhouse by means of windbreakers such as a wall, fences or trees. Size, location and type of windbreaker shall depend on each site condition.

a. Windbreakers shall not be a solid barrier and shall have at least 50% to 60% open space.

b. They shall be located at a distance required by paragraphs 1 or 2 below, whichever is most.

   1) Section 11.2.3 requirements for location of obstructions.

   2) Windbreakers shall be located away from the greenhouse at a distance equal to 4 to 6 times the height of the ridge.

c. Windbreakers shall be extended 50 ft. wider than the greenhouse.

d. Fences shall be used when windbreakers are required immediately. They shall be 50% to 60% porous and not have openings greater than 6 inches.

e. When using a fence type windbreaker, height of the wall shall be equal to the ridge height.

f. Four to five rows of a mixture of deciduous and coniferous trees shall be installed in the wind direction when using trees as a windbreaker.

g. In heavy snowstorm areas, if trees are to be used as a windbreaker, trees shall be trimmed from the base to a 10% to 20% of their height to keep snow from clogging the windbreaker.

PART 3. ARCHITECTURAL AND STRUCTURAL REQUIREMENTS

11.3.1 General.

a. **Acceptable Greenhouse Configurations:**

   1) The greenhouse structure(s) shall be arranged in one of the three different configurations: detached as in Figure 11-4, or attached as in Figures 11-5 and 11-6.

   2) A minimum of 20 ft. shall be provided between the greenhouse sidewalls and adjacent structures, or alternatively, sidewalls shall be designed to carry snow drift loading from adjacent structures. However, the spacing of parallel greenhouses shall be no less than

specified in Section 11.2.3, Tables 11-2 through 11-5.

b. **Plan Dimensions:**

1) Dimensions specified herein are nominal unless otherwise stated. Actual dimensions may vary according to manufacturer's products, within the following ranges: width (+) or (-) 1 ft.; post spacing along sidewalls (+) or (-) 6 in., eave height (+) or (-) 6 in.

2) The width of the greenhouse structure(s) shall be as shown in the prototype plans (Figures 11-7 through 11-12); these are 18, 25, 32, or 42 ft. There shall be no interior posts.

3) The overall lengths of the standard prototype structures shall be as shown in the prototype plans (Figures 11-7 through 11-12). These are:

3 bays x 12 ft.- 4 in.	+/-	7 bays x 12 ft.- 4 in.
4 bays x 10 ft.- 3 in.		8 bays x 12 ft.- 4 in.
4 bays x 12 ft.- 4 in.		10 bays x 10 ft.- 3 in.
5 bays x 10 ft.- 3 in.		9 bays x 12 ft.- 4 in.
5 bays x 12 ft.- 4 in.		11 bays x 12 ft.- 4 in.
6 bays x 10 ft.- 3 in.		

4) The standard post spacing along the sidewalls shall be either 10 ft.- 3 in. or 12 ft.- 4 in. on-center, depending on the chosen glazing system. In heavy snow load regions, this post spacing may be reduced to 8 ft.-7 in. (+) or (-) as required for structural integrity.

5) Corridors shall have a minimum nominal width of 10 ft., 12 ft. wide corridors are recommended where equipment storage or the use of hand-trucks is anticipated.

c. **Roof**

1) The greenhouse roof shall be gable type with a nominal 6:12 pitch.

2) The greenhouse interior shall have a minimum of 9 ft. and a maximum of 11 ft. clearance to the underside of the roof eave.

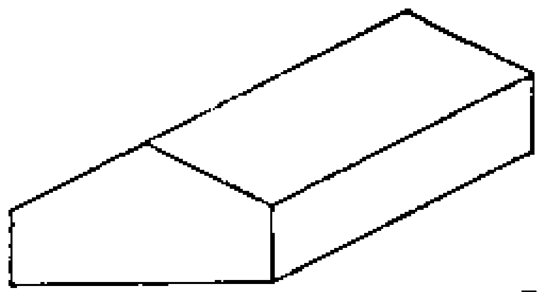


FIGURE 11-4
REFERENCE TO PROTOTYPE
PLANS A & B

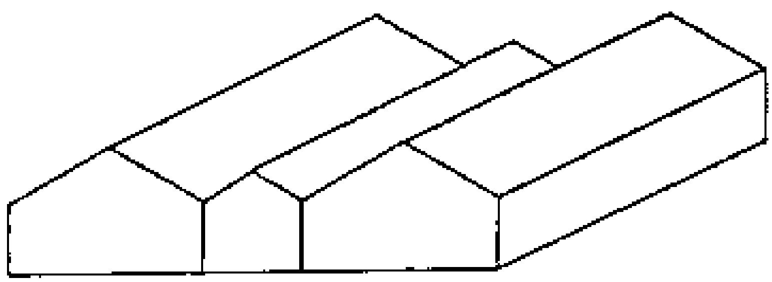


FIGURE 11-5
REFERENCE TO PROTOTYPE
PLAN C

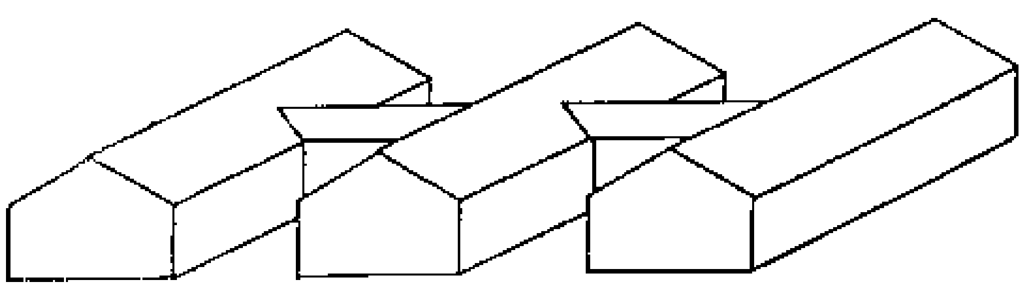


FIGURE 11-6
REFERENCE TO PROTOTYPE
PLAN D

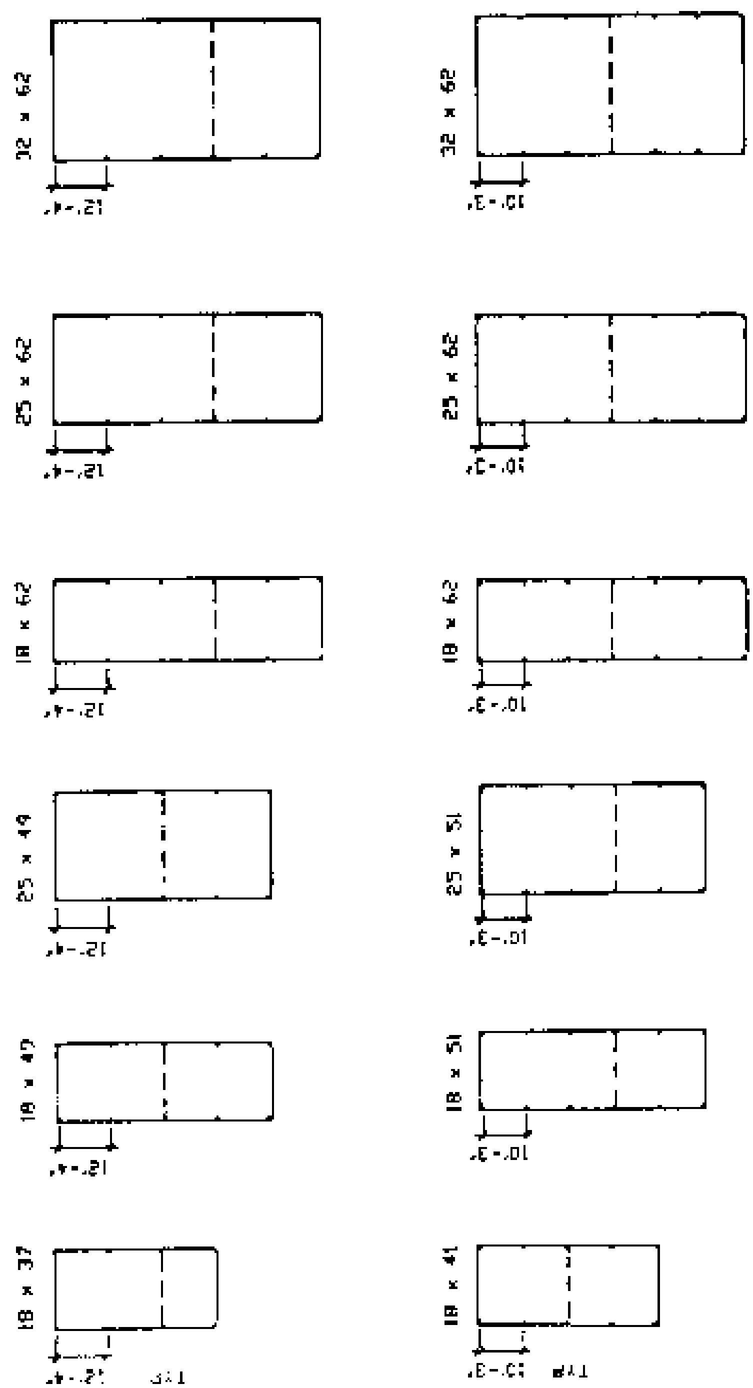
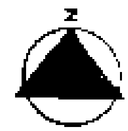


FIGURE 11-7 - PROTOTYPE A PLANS



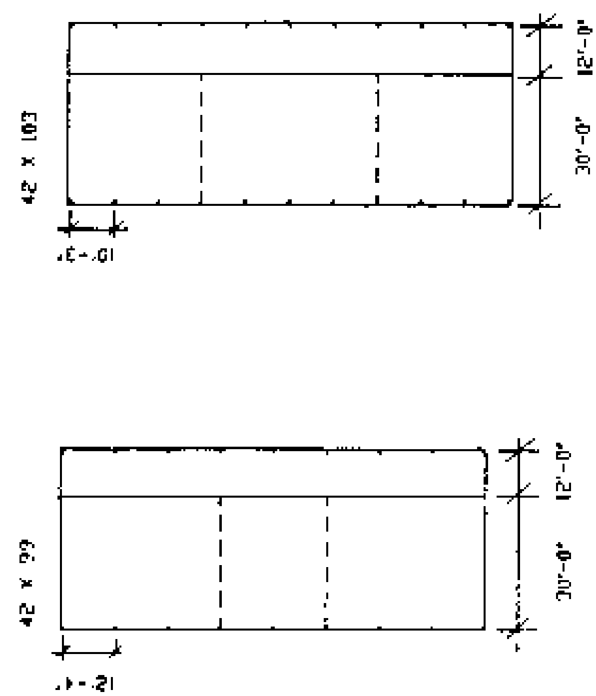
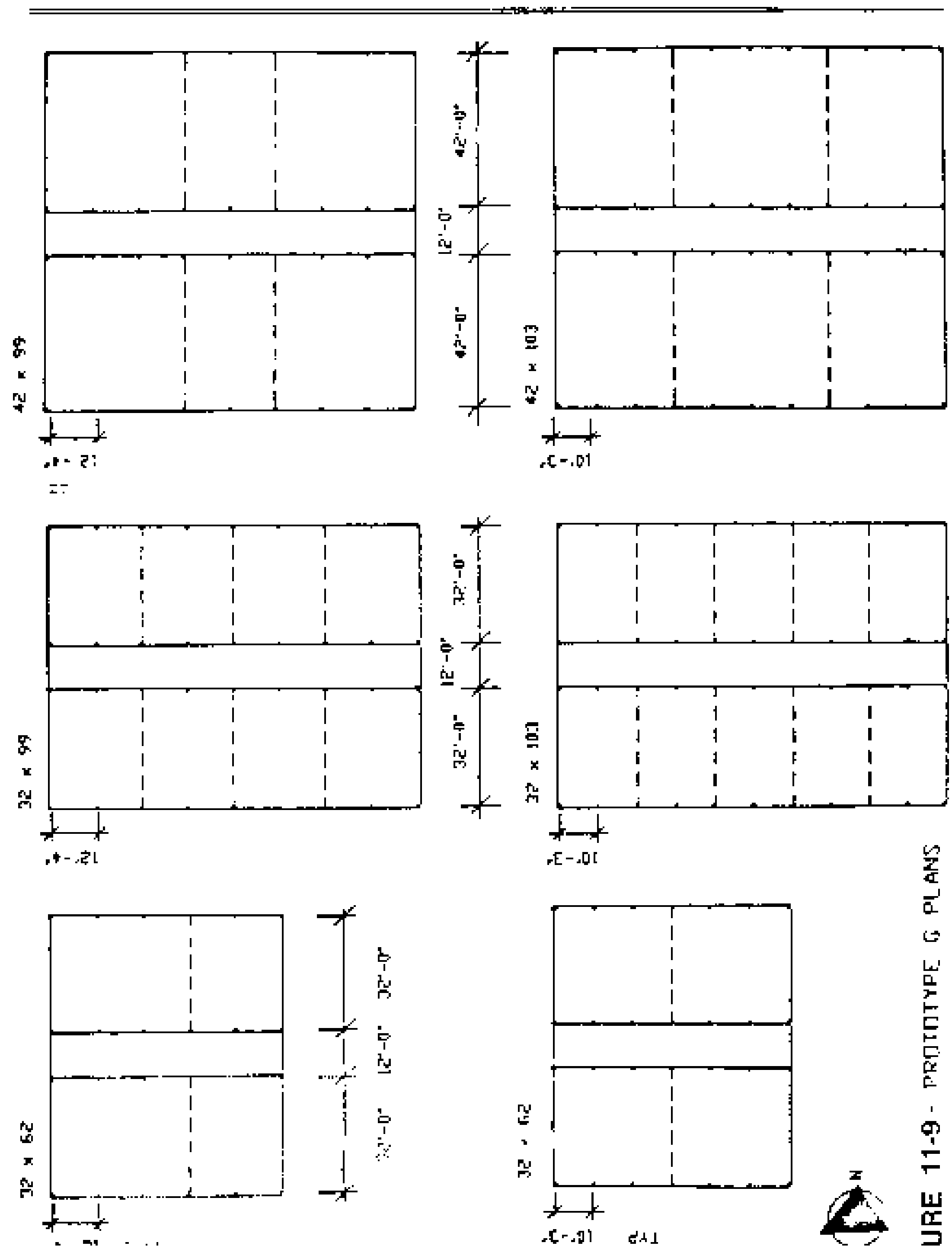


FIGURE 11-8 - PROTOTYPE B PLANS



URE 11-9 - PROTOTYPE G PLANS

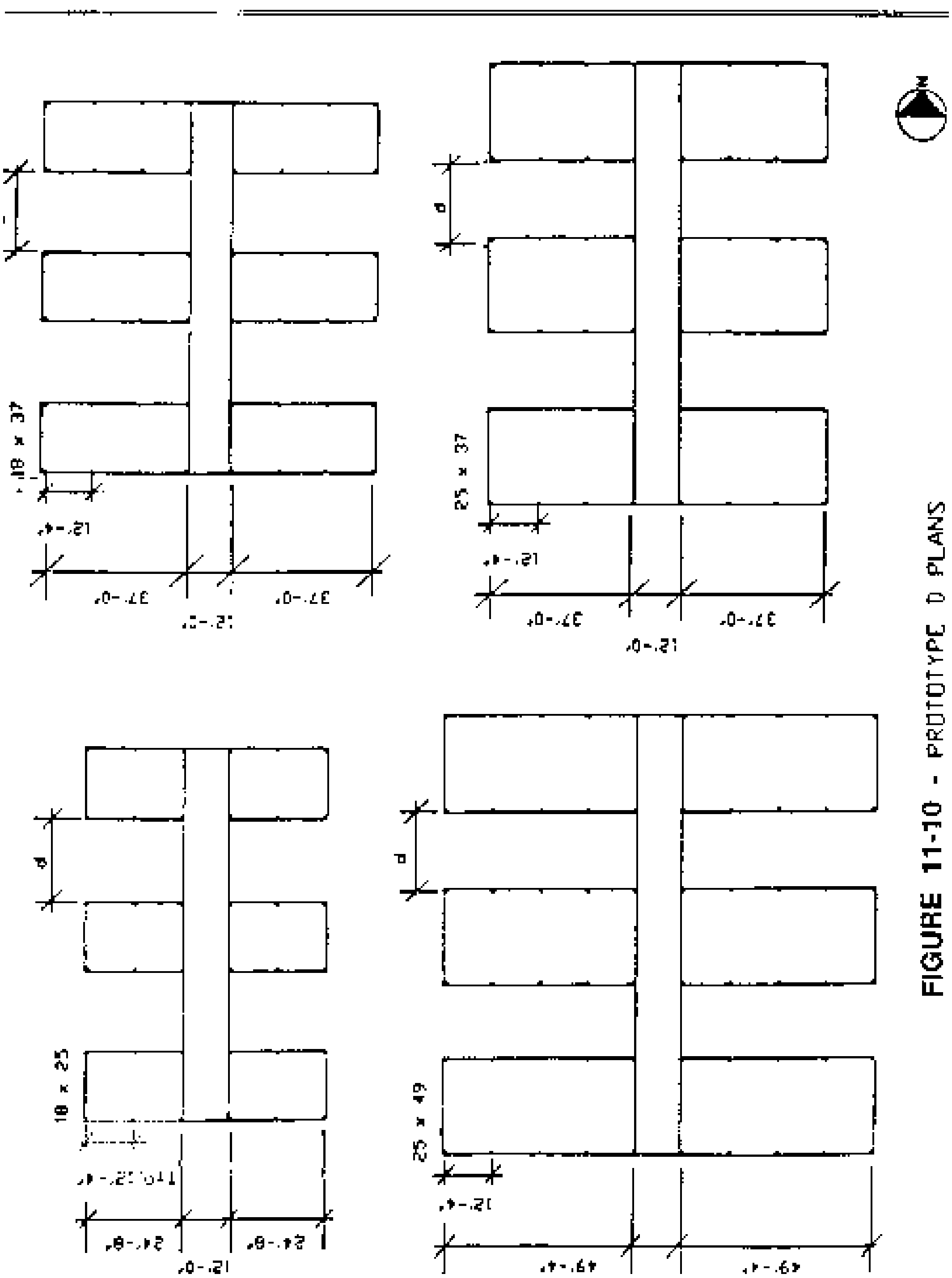


FIGURE 11-10 - PROTOTYPE D PLANS

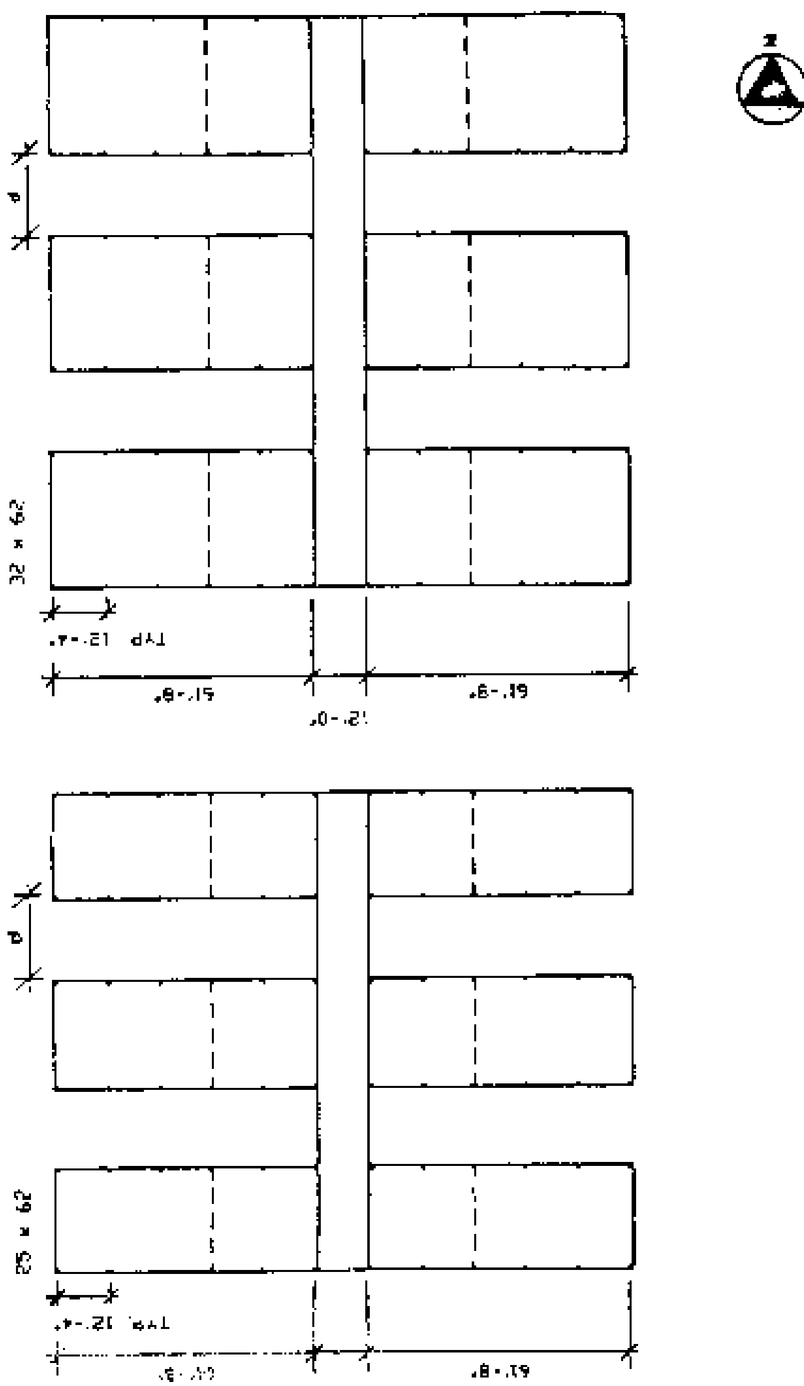


FIGURE 11-11 - PROTOTYPE D PLAN

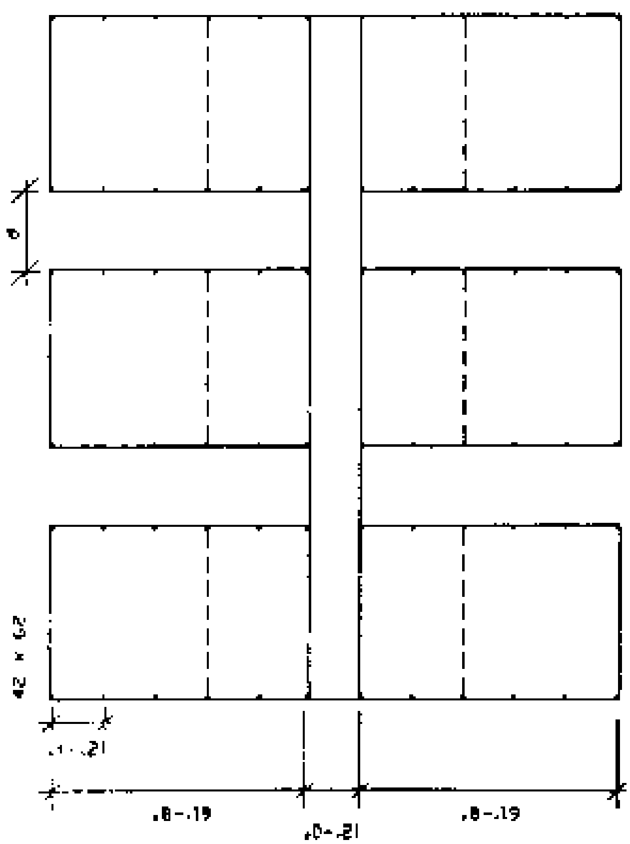


FIGURE 11-12 - PROTOTYPE D PLAN

11.3.2 Structure.

a. **Performance:**

All members (including but not restricted to secondary framing members such as glazing bars, purlins, lugs, sash mounting, vent headers, eave plates and transom sills) shall be examined for all applicable load combinations, and design certification shall so state.

b. **Design Load Criteria:**

The structure(s) shall be designed to carry the following loads: Dead load; snow load; wind load; seismic load; equipment live load; and combined load cases as prescribed by the applicable building code. Dead load for all structures shall be calculated using a glazing weight equal to or greater than the weight of double pane insulating glass, where one pane of glass is tempered float glass and the other one is laminated tempered float glass. Where equipment loads are not located at panel points of trusses, secondary bending stresses in truss members shall be accounted for.

c. **Deflection Limitations:**

1) The maximum allowable deflection for structural members shall be 1:180 of the length of the member.

2) Glazing bars and mullions supporting glass shall limit deflection to 1:175 of the length of the glass lite being supported.

d. **Framing Materials:**

1) Primary framing members and connectors shall be either mill finish extruded aluminum or galvanized steel.

2) Secondary framing members such as glazing bars, ridges, eaves, gutters, sills, doors and frames, shall be of extruded aluminum alloy and shall be either mill finish or other approved finish to prevent corrosion due to environmental conditions.

e. **Framing and Bracing:**

1) Roof framing members shall be of uniform design and adhere to a set pattern.

The frames shall be either clear span roof trusses supported on braced posts or rigid frames.

2) The greenhouse structures shall be designed with adequate wind bracing to resist racking in the longitudinal direction. As a minimum, provide diagonal bracing in the middle bay of the sidewalls and roof.

f. **Trusses:**

1) All truss members and connecting plates shall be designed to carry the required design loads. Bottom chords shall be designed for compression loads due to wind pull. Bridging, if required, shall be provided.

2) Coordinate the location of roof truss members with the mechanical equipment, e.g. "fan jet".

g. **Truss Supports:**

1) Trusses shall be connected to side posts by a plate designed to be bolted to the web of the side post with all bolts in shear, and bolted to the truss rafter and bottom chord in shear, forming a concentrically loaded joint. No connection detail shall be allowed, that is fastened to the flange of the post thereby placing fasteners in tension or twist.

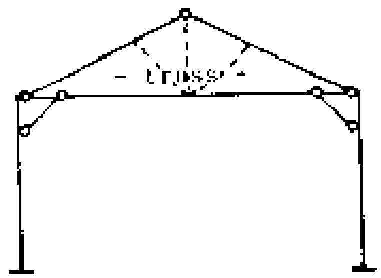
2) Knee braces connecting the side posts to the bottom chords shall be added as required to prevent racking due to wind and seismic conditions.

h. **Purlins:**

1) Purlins shall be prefabricated before shipment for the attachment of glazing bars and connecting lugs.

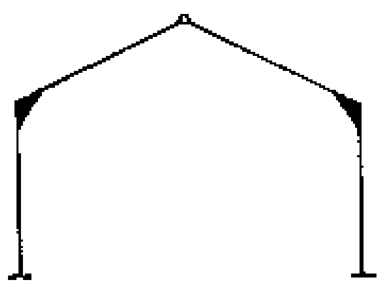
2) Purlins in the roof, gables and partitions shall be connected to supporting members with a minimum of two bolts into each connecting member.

3) Roof purlins shall be spaced at a maximum of four ft. nominal on center and shall be spaced more closely if required to meet design load criteria.



TRUSS ROOF
FRAME

FIGURE 11-13



RIGID
FRAME

FIGURE 11-14

i. **Rigid Frames:**

Rigid frames may be used instead of truss roof construction. Each frame shall consist of two main rafters, connected to their sideposts with a moment connection which provides adequate rigidity against racking.

j. **Attachment to Foundation:**

1) Attachment to foundation shall be adequate to resist all loads including overturning and pull Posts shall be bolted to, or embedded in, either a concrete foundation or a reinforced poured concrete or reinforced masonry wall as shown in Figures 11-15a through 11-15c.

2) Extruded aluminum wall sills shall cap the foundation or knee walls, as shown in Figures 11-15a through 11-15c, by lugging or bolting directly to the foundation. Vertical joints of concrete foundation walls shall occur at frame locations. The bottom side of sills shall receive one coat of asphalt paint before setting in place.

11.3.3 Envelope.

a. **Glazing Materials:** General

1) Acceptable glazing materials are tempered glass; laminated glass (for roof glazing only); twin-wall rigid acrylic sheets; and U-V resistant twin-wall polycarbonate sheets.

2) Design load capabilities and allowable spans shall be obtained from the glazing manufacturer and adhered to in the design.

3) Wall panels surrounding electrical equipment or controls shall be of non-combustible material for a distance of 12 in. from the panel.

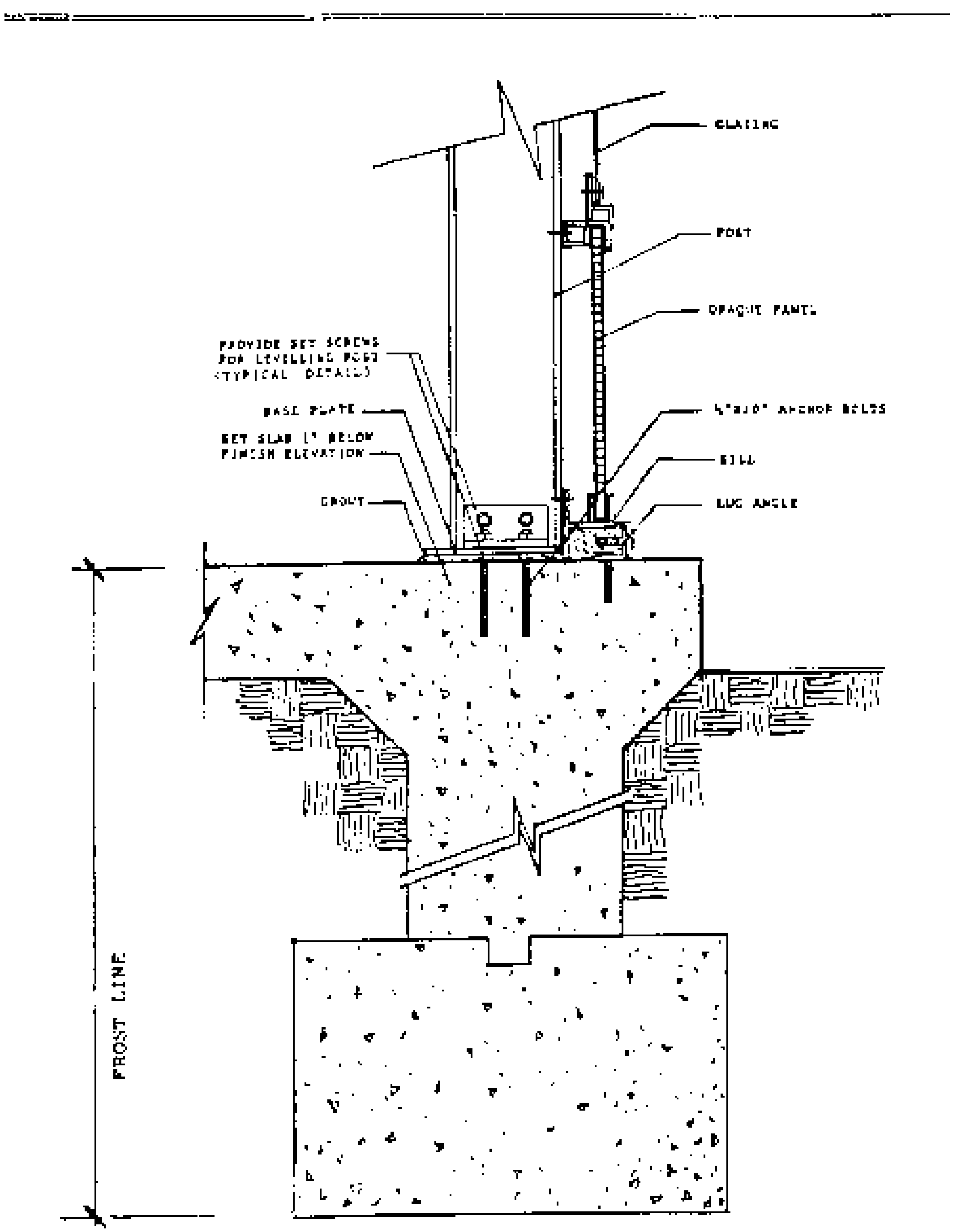


FIGURE 11-15A

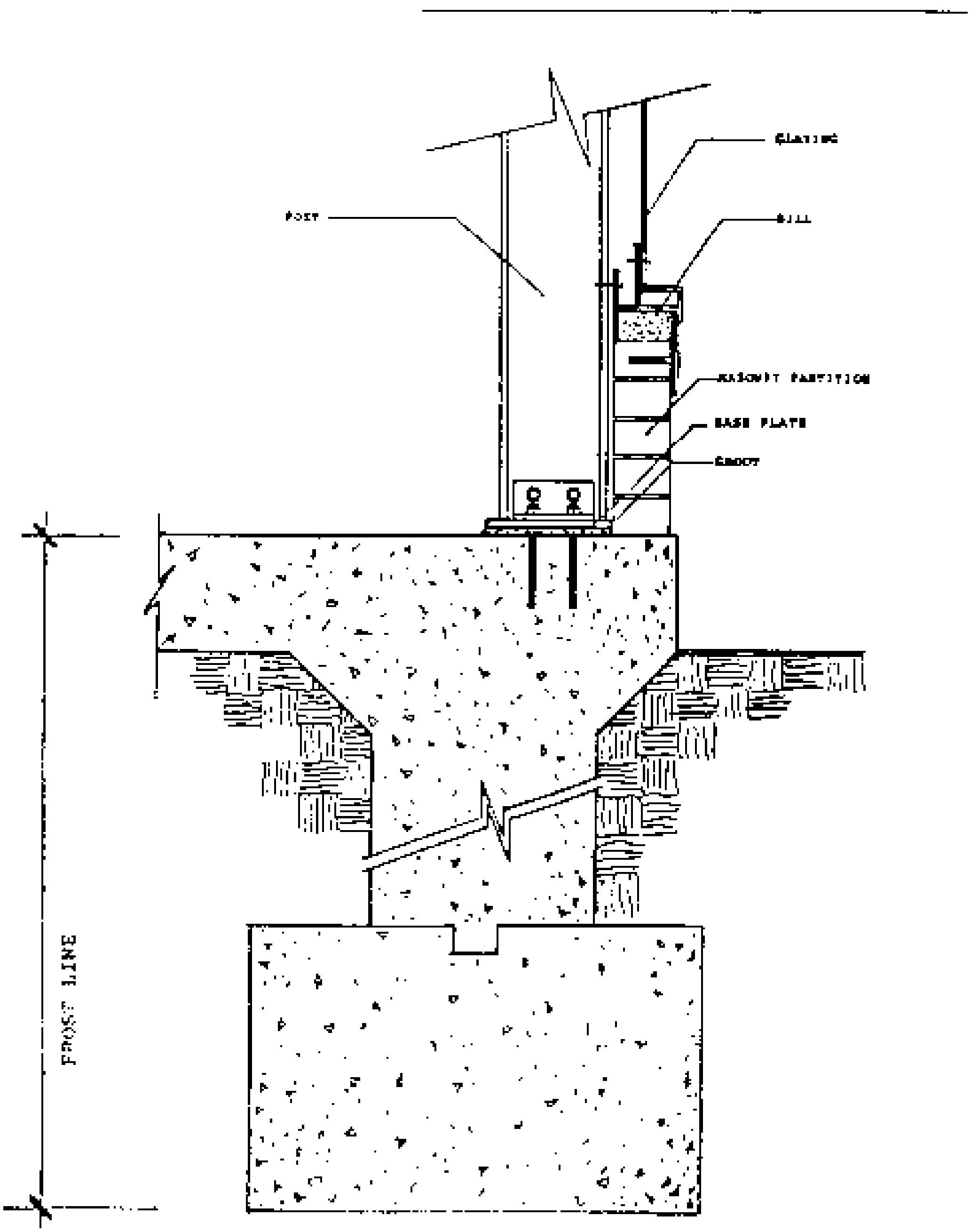


FIGURE 11-15B

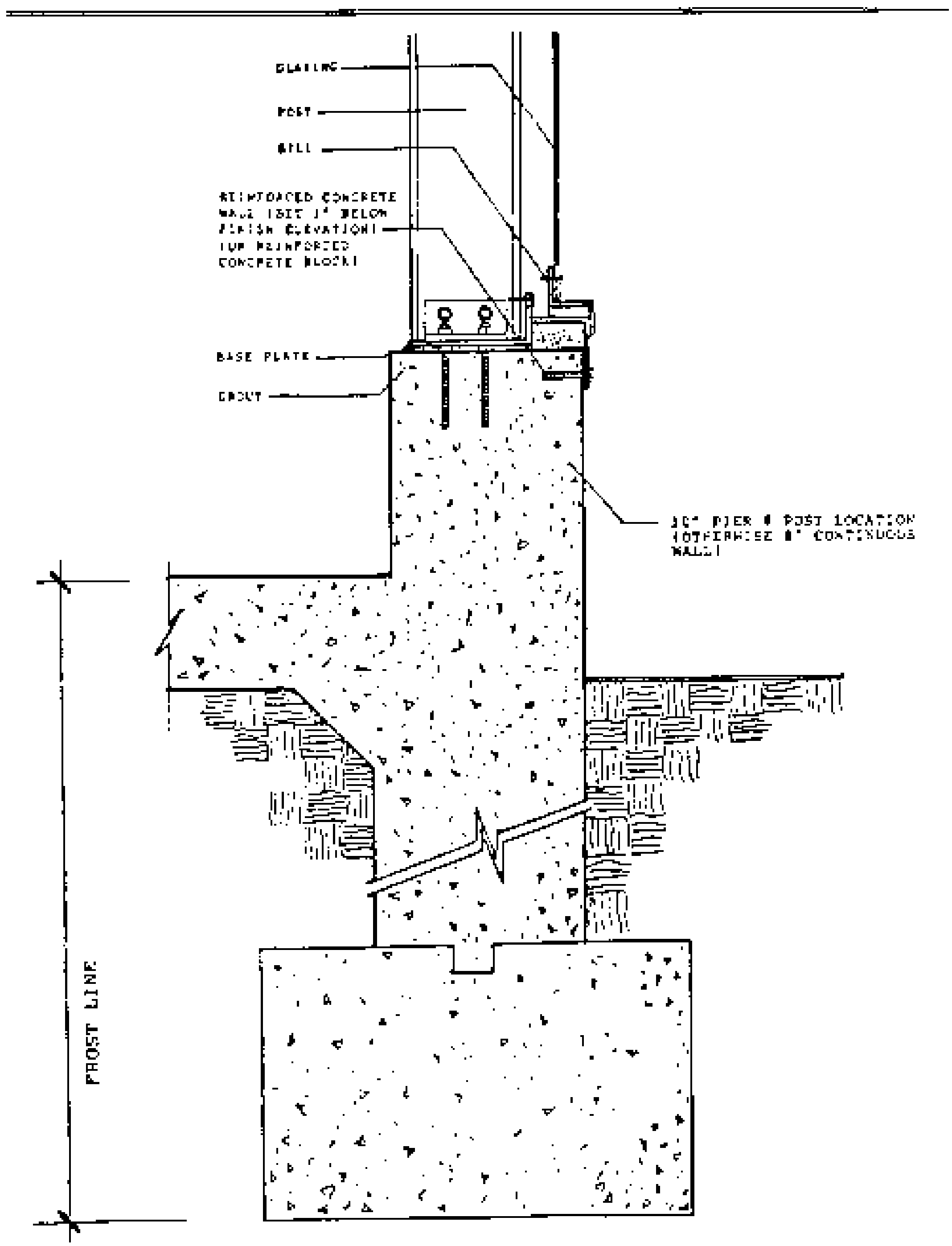


FIGURE 13-15C

b. **Glass:**

The following types of glass units are acceptable and should be chosen based on climate conditions, cost, and for aesthetic and structural reasons:

1) **Single pane tempered float glass:**

(a) The glass shall be 1/8 in. thick clear, or 1/8 in. thick low-iron clear.

(b) All except the top lites of glass shall be laid with 3/8 in. minimum lap joints, and held in place with aluminum bar caps to cover the glazing edge, and to prevent the glass from slipping. These caps shall have proper forming to exert a uniform, but not excessive pressure along the entire length of the glass lite. All lap joints shall be unsealed.

(c) The top lites and anywhere leakage is a potential problem shall be butt glazed and sealed. Between lites, butt glaze with h-cane bars. All butt glazed joints shall be sealed with silicone or butyl sealants.

(d) Glazing bedding tape of the same general properties as the aforementioned elastic glazing sealants may be used for bedding glass. Where such tape is used for bedding, the glass shall be sealed on the outside with a bead of glazing sealant throughout its entire length before applying aluminum glazing caps to the bar.

2) **Single pane laminated float glass:**

This glass type shall be used for roof glazing only. It is recommended for consideration at sites and or operating conditions where glass breakage may pose an unusually high safety risk, as determined by ARS. One such condition may be encountered in seismic zone 4.

Use 3/16 in. laminated annealed glass, or 5/16 in. laminated tempered glass. Butt glaze all laminated glass as recommended in Single pane tempered float glass above.

3) **Double pane insulating glass units:**

(a) This glass type shall be considered for use in regions with severe climate conditions and high energy costs, and/or where replacement of glazing is not contemplated for a long time period (as in Level 3 greenhouses).

(b) The units shall be composed of two panes of glass as described above. The panes shall be hermetically sealed as specified in the ASTM E774 standard. The space between panes shall be at least 1/4 in. but no more than 1/2 in.

(c) Where insulating glass units are used in roof glazing, the inner pane of glass shall be laminated.

(d) All insulating glass units shall be butt glazed and glazing bars shall be designed to prevent leakage and to provide continuous support for the glass units.

4) **Low-emissivity (low-E) insulating glass units:**

(a) This glass type shall be considered for use in sidewalls and gable end walls only. The units are as described in double pane insulating glass units above, with a low-emissivity coating on the inside surface of one of the glass panes.

(b) Refer to AIA, Architectural Graphics Standards, Chapter 8, for acceptable glazing details for mounting insulating glass units on metal frames.

c. **Acrylic Glazing:**

1) Acrylic glazing shall be clear twin-walled sheets of at least 16 mm (5/8 in.) nominal thickness.

2) Acrylic sheets shall be supported on all four sides. The acrylic glazing shall be 4 ft. wide sheets continuous from the ridge vent sash to the eave and from side vent sash to sill. Field cutting of acrylic sheets shall be only as approved by manufacturer.

3) The acrylic sheet shall not be point-fastened to glazing bar system; it shall be allowed to float in glazing system and held at bottom.

4) Acrylic sheets shall be dry-glazed or gasketted with EPDM rubber or other compatible materials, as recommended by the manufacturer.

5) The glazing manufacturer shall be consulted for compatible herbicides and pesticides and other materials that may come in contact with plastic glazing.

d. **U-V Resistant Polycarbonate Glazing:**

1) Polycarbonate glazing shall be clear twin-walled sheets of at least 8 mm (5/16 in.) nominal thickness.

2) Polycarbonate glazings shall be coated or treated for resistance to ultraviolet light degradation. The glazing sheets shall not lose more than 6% of initial light transmission

after 10 years of life, as per ASTM test standard D - 1003.

3) The polycarbonate glazing sheets shall be one piece from ridge vent sash to eave and from side vent sash to sill.

4) The polycarbonate glazing sheets shall be point-fastened to the glazing bar system and/or to the purlins according to glazing manufacturer recommendations.

5) The glazing manufacturer shall be consulted for compatible herbicides and pesticides and other materials that may come in contact with plastic glazing.

e. **Glazing Bars:**

1) An aluminum glazing bar system shall be provided with internal gutter system to carry condensate to eave and sill.

2) Roof glazing bars shall be one piece from ridge vent sash to eave. They shall be raised off purlins with clasps, permitting condensation to run down to eaves without interruption.

f. **Condensation Control:**

1) The design of the greenhouse shall incorporate a system of collecting and draining off all condensate.

2) The vent headers shall catch the condensate formed on the ridge and vents, the rafters shall catch condensate from purlins. The eave shall be drained to the ground or to an inside drain. Gutters and downspouts should be provided for exterior drainage at roof valleys.

3) Optional: The glazing may be field or factory coated with a condensation control surfactant.

g. **Opaque Panels:**

1) Opaque panels shall be used instead of glazing in the lower 2 ft.- 0 in. to 2 ft. 6 in. of the greenhouse walls. They may be prefabricated insulated panels (max U-value = 0.25) or masonry block or poured concrete structural knee-walls.

2) In cold climates, the entire north wall may be composed of insulated opaque panels or masonry.

h. **Ridge:**

An extruded aluminum ridge shall be furnished and placed at the peak of the structure. Ridge shall be provided with continuous hinge flanges to receive ridge ventilating sash on each side of the ridge. Condensation gutter shall be provided in lower part of the ridge to divert condensation to drip gutters of roof bars.

i. **Eave Plate:**

1) Extruded aluminum eave plates shall be provided.

2) Eave plates shall have a flange to receive glazing bars and shall be provided with weep holes and a condensate gutter to carry condensation collected from the underside of the roof.

3) The eave plate shall include a continuous hinge element which allows the installation of an outswinging sash.

4) Joints of this eave plate shall occur at main frame locations (i.e. posts).

j. **Gutter:**

1) An extruded aluminum gutter with downspouts shall be provided at roof valleys.

2) In regions with 20 psf or greater snow load, the gutters shall be equipped with heating coils, in order to prevent gutter blockage. Alternatively, hot water returns shall be located under the eave.

k. **Wall and Vent Sills:**

1) Extruded aluminum sills shall be provided where shown on drawings.

2) Sills shall be capable of receiving either side vents or fixed glazing, as required.

l. **Doors:**

1) Exterior doors should be located such that stairs are not required. Where ground is sloped provide paved ramps. Ramps shall comply to ANSI Handicapped Standards.

2) Doors and frames shall be extruded aluminum.

3) Doors shall consist of two panels, the upper of which will be tempered. The lock rail

between panels on all doors shall be not less than 30 in. above the floor.

4) Doors in interior partitions shall be of the same construction as exterior doors. Doors may be sliding type or swinging type. Sliding doors shall be equipped with aluminum or stainless steel sliding door track and hardware, furnished with flush pulls and with door stops. Swinging doors shall be furnished with standard locksets, closers and hinges.

m. **Vents:**

1) Operable vents shall be provided at both ridge and exterior sidewalls.

2) Vents shall be made up of a top rail, bottom rail and muntins of extruded aluminum and bolted together in accordance with manufacturer's instructions, and shall be furnished with a continuous hinge, and arranged to open out.

3) Vents shall be continuous along the length of the greenhouse.

4) Vent Operation - Incorporate operators for roof and sidewall ventilating sashes in each greenhouse compartment. Provide motorized step control operators as required. Fabricate operator to include positive stop controls to prevent the ventilating sash from operating beyond the hinge limit at full opening and beyond the sill stop at the closed position. Provide a convenient disconnect for manual operation in the event of a power failure. Refer to Mechanical and Electrical sections of this design guide for additional information on automatic controls.

n. **Demountable Glazed Partitions:**

1) Movable partitions between growing areas may be incorporated in the design. These shall be configured such that they may be repeatedly removed and relocated, at any frame.

2) The partitions shall be non-load bearing and independent of the roof support system.

3) The glazing shall be unsealed, dry-gasketted.

o. **Flashing:**

1) Provide flashing and counter-flashing as required where greenhouse butts against adjacent structure(s).

2) All flashing and counter-flashing shall be either aluminum or lead coated copper.

3) Flashing details shall be designed to accommodate thermal expansion and/or wind drift of up to 1/2 in.

p. **Floors and Drainage:**

Floors shall be concrete slabs sloped away from aisles and drained.

11.3.4 Solar Radiation Control and Movable Insulation.

a. **General:**

1) All greenhouses shall be provided with means of reducing the solar heat gain.

2) The methods used for shading shall be under user control. Deciduous trees as means of shading are not considered to be under user control.

3) Shading shall be implemented using shading compounds and/or movable shading screens. Other solar control techniques are acceptable provided they comply with requirements (1) and (2), stated above.

b. **Shading Compounds:**

Shading compounds may be used for Level 1 and Level 2 greenhouses only.

1) **Shading Compound Performance:**

(a) The manufacturers of enclosure materials shall be consulted for the compatibility of the shading compound with their product and also on restrictions with respect to the application and removal procedures of the shading compound.

(b) Shading compounds shall be non-corrosive, non-toxic and shall not affect the enclosure materials of the greenhouse. The enclosure materials may include, but are not limited to, paint, putty, glass, acrylic, polycarbonate, galvanized steel and aluminum.

2) **Method of Application:**

(a) The degree of shading desired shall be established before the shading compound is set for application. Crop grown shall determine the shading compound density.

(b) Application of shading compound by spraying method shall be accepted only for Level 1 greenhouses. For Level 2, roller or brush method shall be used.

(c) High density of shading compound shall be achieved by applying several coats of fine coats rather than one heavy coat. Over spray shall not harm the crop.

(d) Shading compound shall be thoroughly stirred before application. It shall be uniformly distributed on the greenhouse surface.

(e) Shading compound shall be applied during warm, dry weather when rain is unlikely for 24 hours. It shall form good adhesion with the receiving surface, which shall be clean and dry.

(f) Storage, application, drying time and removal shall be as specified by manufacturer.

3) **Waste Compound Disposal:**

(a) Waste compound shall be disposed of in accordance with the local, state and federal regulations. Prior approval must be obtained before disposing of any toxic materials.

c. **Shading Screens:**

1) Movable shading screens may be used in all greenhouses.

2) Design and shading percentage of shading screens shall depend on climate and the shading criteria established for the vegetation grown in the greenhouse. Such data shall be provided by the user of the greenhouse.

3) Moving operations can be manual or automatic. All shading material shall be light weight, easy to work with and store.

4) **Method of Application:**

(a) Screens shall be permanent when installed inside the greenhouse. Removable exterior shading covers on the exterior shall be allowed for Level 1 greenhouses, but for Level 2 and 3 they shall only be used in emergency situations.

5) **Shading Material Performance:**

(a) Shading screen material shall be compatible with the plastic glazing products of the greenhouse, where applicable.

(b) Shading materials shall have fire retardant properties to comply with the local code requirements.

(c) Screens shall have a minimum 1-year guarantee. Manufacturer of the material shall guarantee the performance of material over its life span for resistance to ultraviolet light degradation and shrinkage in the material.

(d) Maximum shrinkage shall be 3 in. in either linear direction. Shrinkage shall be accounted for at the time of installation.

6) **Installation And Operation:**

(a) Shading material shall be moved uniformly across the whole width. Spacing of hooks and staples shall be as recommended by the manufacturer of shading material.

(b) All joints, edges and other high stress areas during the operation shall be adequately reinforced. Suspension hooks, wires and other operating devices shall be of non-stretchable and rust proof materials.

(c) Installation of movable screens, either truss to truss (peak or flat) or gutter to gutter (flat) system, shall be at the discretion of the designer. When installing flat screens, mechanical and electrical items shall be coordinated in the design.

(d) Movable screen operating systems shall be compatible with the material and shall not create a permanent obstruction in the circulation space.

(e) Movable screens shall not come in contact with any moving equipment. During the opening cycle, material shall have an even lapping and compact gathering. The lead edge shall form a tight seal when in full closed position.

d. **Movable Insulation:**

Insulation material may be used in all levels of greenhouses. Movable insulation can be operated manually or with automatic equipment.

1) **Insulation Material Performance:**

(a) Insulation material shall be compatible with the plastic enclosure elements of the greenhouse with which it makes contact.

(b) Insulation material shall have fire retardant properties to comply with the local code requirements.

(c) It shall yield a minimum life expectancy of 5 years for Level 1 and 2, and of 8 years for Level 3 greenhouses. Manufacturer of the material shall guarantee the performance of material over its life span for resistance to climatic conditions and shrinkage of material.

(d) Maximum allowable shrinkage shall not be more than 3 in. in either linear direction. Any shrinkage expected during its use shall be accounted for in the installation.

2) **Installation And Operation:**

(a) Design of movable insulation shall be such that it does not significantly block light during the day. When stored in folded condition, it shall present as little obstruction as possible to direct solar radiation. Movable insulation shall be stored along the North wall under the gutter in prototype plans A and D (Figure 11-4 and 11-6), and along the corridor wall in prototype plans B and C (Figure 11-4 and 11-5).

(b) Installation of thermal insulation, either truss to truss (peak or flat) or gutter to gutter (flat) systems, shall be at the designer 's discretion. When installing flat insulation, mechanical and electrical items shall be coordinated in the design. To ensure that the covers are properly supported, the insulation shall not travel more than 24 ft.

(c) When opening the insulation material in the morning, appropriate time shall be allowed for the sun to warm up the attic air.

(d) During the opening cycle, material shall have an even lapping and compact gatering. The lead edge and ends shall form a tight seal when in fully closed position.

(e) Insulation material shall be moved uniformly across the whole width. Spacing of hooks and staples shall be as recommended by the manufacturer of insulation material.

(f) All joints, edges and other high stress areas during the operation shall be adequately reinforced. Suspension hooks, wires and other operating devices shall be of non-stretchable and rust proof materials.

(g) Movable insulation material shall not touch the outside glass or plastic enclosure of the greenhouse. A minimum air gap of 6 in. shall always be maintained. Material shall not come in contact with any moving equipment.

3) **Condensation:**

(a) Condensation shall not collect on the fabric.

(b) Porous materials that have water absorption properties shall be used in such situations or the material shall be sloped to drain the condensate water away from the plants.

e. **Equipment and Controls for Movable Shading Screens and Movable Insulation:**

1) **Equipment:**

(a) The operating equipment shall be adequately designed and compatible with shading and insulation material.

(b) Equipment shall be constructed of materials that can withstand changes in humidity and temperature, and the effects of chemical agents and fertilizers without rusting or otherwise deteriorating.

(c) All automatic equipment shall be designed with safety devices and a manual backup system.

(d) All automatic operating systems shall be equipped with limit switch, safety cutoff switches and backup torque switch.

(e) All mechanical systems shall be inspected and maintained periodically as specified by the manufacturer.

2) **Controls:**

(a) Automatic control system shall have a minimum of 24 hour clock programming capability.

(b) A percentage timer shall be provided when using automatic control for the opening of insulation in the morning.

(c) The control panel shall have a precision time-limit switch and manual override prevention system in either directions.

(d) All controls shall be housed in a waterproof enclosure. Low voltage circuits shall be provided for connection to mechanical and torque limit switches. Manual-off-automatic and cover-uncover switches shall be mounted on the panel front.

11.3.5 Benching.

a. **General:**

Benching provisions in a greenhouse shall be designed for convenience, flexibility in use, strength, and low-maintenance. The design criteria provided below applies to greenhouses used for research operations.

b. **Space Utilization:**

1) Exact benching configurations depend on the dimensions of the greenhouse compartments and the needs of the researcher.

2) Aisle widths shall be 2 ft. minimum.

3) Greenhouses for research operation shall have a space utilization efficiency of minimum 50%.

c. **Benching Size:**

1) When easy movement is important, benches shall not be longer than 6 ft.

2) The width of the research benches should not be more than nominal 4 ft. When plants are frequently measured, the width of the bench should be nominal 3 ft.

3) Bench heights should be adjustable. The height of the bench shall be determined by the type of crop to be grown. The average bench height is 30 in. For tall plants (3-4 ft.), benches should be approximately 24 in. high and for shorter plants, 34 in. high.

d. **Benching Flexibility:**

1) Flexibility in bench design shall be such that they can be moved or dismantled when required.

2) An "erector" type construction shall be used to allow flexibility in bench configuration to fit the research need.

e. **Benching Materials:**

1) Benches shall be able to withstand steam sterilization water, fertilizers, soil and other chemicals. They shall be durable, require low maintenance and ease of change in configuration.

2) Bench framing shall be galvanized steel, stainless steel, or aluminum.

3) Any benching material used for bench tops shall be properly supported and shall not sag or stretch.

4) Open top benches are commonly used with potted plants and bedding plants since they allow air circulation and water to run off thereby reducing insect and disease problems. Galvanized expanded metal makes a strong bench surface. Wood lath is an acceptable lightweight bench surface for potted plants or flats. Cedar or redwood lumber provide a longer life. Standard widths are 4 ft. and 6 ft. To prevent small pots tipping, a light wire mesh can be placed over the lath.

5) Materials commonly used for solid top benches include aluminum or galvanized steel, and preservative-treated plywood. Lightweight molded plastic or reinforced fiberglass bench tops are some other options that make movement easier.

f. **Bench Strength:**

The bench shall be strong enough to hold 50 lb/sq. ft. Frames shall be provided with lateral and diagonal bracing.

11.3.6 Movable Growing Systems.

a. Movable growing systems are manufactured primarily for commercial growers. Since there are some differences between research and commercial growing requirements, the movable systems typically available may have to be adjusted for research operations. Note differences between top widths in 11.3.5(c)(2) and 11.3.6.(e)(1).

b. There are two types of movable growing systems: movable benches and transportable trays or pallets. Movable growing systems can increase the growing area up to 90% of the total greenhouse floor area.

c. **Movable Benches:**

1) The simplest movable bench system to install is one in which the benches remain in the greenhouse but move on rollers placed over a supporting frame to provide aisle space. Bench layout can be either across the length or width of the greenhouse. In greenhouses longer then 100 ft. a crosswise direction may be more convenient, to reduce the distance

plants have to be moved. For crops where a floor heating system is installed, movable benches can be supported near the floor.

2) Problems associated with movable benches include the difficulty of moving large quantities of plant material and limited maneuverability in the aisles. Placing or removing plants can be accomplished with a narrow belt conveyor that folds for transport. The conveyor is placed in the aisle between the benches and the plants are hand loaded or unloaded.

d. **Tray Systems:**

1) A more complex installation uses modular trays or pallets that move sideways to create a work aisle and lengthwise for removal to the work area. All transplanting, pot filling, pinching and other necessary operations are handled in the work area. The trays are moved manually on rails or carts or mechanized to move on conveyors.

2) Because tray systems are more expensive than movable benches, they are generally economical for crops that remain in the benches for less than four months, or for crops which require frequent spacing, pinching, disbudding, etc.

e. **Design of Movable Bench Systems:**

1) The standard available widths for movable bench tops are 5 ft., 5 ft.-6 in. and 6 ft., to allow access to the center from both sides and to allow enough bench movement to get adequate aisle space without the bench tipping off the rollers. Note that the recommended bench width in 11.3.5(c)(2) is 4 ft. for research purposes. Movable benches are produced wider since they are primarily sold to commercial growers.

2) Tray bench tops can vary in sizes (5 ft. x 6 ft. 6 ft. x 8 ft. and 6 ft. x 10 ft.) to as wide as 8 ft. and as long as 40 ft. In selecting a bench width, consider the crop to be grown and the size of bench that will conveniently fit into the greenhouse area.

f. **Movable Bench Support Systems:**

1) Steel pipe or tubing is the most common material for the bench frame. Pipe or tubing of 1-1/2 in. to 2 in. diameter is usually fabricated from commercially available bench fittings. Steel angle or channel (1-1/2 in. to 2 in.) can also be used.

2) Anchor support frames to the ground with concrete piers or set on concrete walks. Lateral and diagonal bracing is needed on unanchored frames.

3) It is important that the tops be level and in line. Depending on the plant load, space

frames from 5 ft. to 10 ft. apart. A sand rooting bed deeper than 3 in. will require greater support.

4) Spacing of the rollers and width of the top of the support frame are critical for adequate bench support and clear aisles. Table 6 gives dimensions for several bench sizes and aisle widths. Maintain a ratio of 2 to 1 for supported to unsupported benches area when benches are in the fully extended position.

g. **Bench Manufacturers**

The following is a partial list of available greenhouse bench manufacturers. Other manufacturers not listed here, may also be acceptable:

- Agra Bench Rolling Bench Systems, Agra Tech., Inc., Pittsburg, CA.
- Criterion Movable Benches, X.S. Smith, Inc., Red Bank, NJ.
- Lord and Burnham Modular Bench Units, Division Burnham Corp., Irvington, NY.
- Ludy Custom Greenhouse Benches, Ludy Greenhouse Manufacturing Corp., New Madison, OH.
- Nexbench Rolling Benches, Nexus Greenhouse Corp., Northglenn, CO.
- Rough Brothers, Inc. Movable Benching, Cincinnati, OH.

TABLE 11-6 DIMENSIONS FOR MOVABLE BENCH SYSTEMS LAYOUT

Bench Top Width (feet)	Aisle Width (inches)	Roller Spacing (inches)	Support Frame length (inches)
4	16	22	32
	18	20	31
	20	not recommended	
4.5	16	28	38
	18	25	36
	20	22	34
	22	not recommended	
5	16	32	42
	18	30	41
	20	28	40
	22	25	38
	24	not recommended	
5.5	16	32	42
	18	32	43
	20	32	44
	22	32	45
	24	28	43
6	16	32	42
	18	32	43
	20	32	44
	22	32	45
	24	32	46

PART 4. MECHANICAL SYSTEM DESIGN STANDARDS

11.4.1 General.

This section of the design manual specifies the design standards for the mechanical systems in ARS standard greenhouses.

11.4.2 Ventilation.

a. **Natural Ventilation:**

Natural ventilation shall be provided by side and ridge vents.

1) Where ridge and side vents are used, they shall be operated automatically by a 3-phase electric motor. These vent systems shall also have the capability to be manually operated from the floor through a gear and chain mechanism. Side vents shall open only when outdoor air temperature is less than 5 degrees F below the setpoint of the greenhouse.

2) Side and ridge vents are to be slow opening and shall withstand a minimum life expentancy of 5 years at an opening and closing occurrence rate of 6 cycles per hour.

3) All side and ridge vents are to obtain a maximum air leakage rate of 2 percent of maximum air flow when fully closed at a pressure differential across the damper of 2 inches water column.

b. **Mechanical Ventilation:**

1) Mechanical ventilation shall be provided by propeller- type exhaust fans.

(a) During heating periods, outside air shall be introduced through the overhead "Fan Jet" heating system and exhausted through two (2) propeller type exhaust fans at the opposite gable end of the greenhouse. The maximum ventilation rate shall be one and a half (1.5) cubic feet per minute (CFM) per square foot of floor area. Each exhaust fan shall have a capacity of one half this maximum ventilation rate.

(b) During cooling periods outside air shall be introduced through side vents and exhausted through propeller type exhaust fans located on the opposite wall. The ventilation capacity shall be limited to cooling design requirements as specified in section 11.4.4.

c. **Variable Ventilating Air Rates:**

1) For Level 2 greenhouses, varying ventilation air rates are to be obtained through multiple fans each equipped with 2 or 3 speed motors.

2) For Level 3 greenhouses, varying ventilation air rates are to be obtained by a combination of multiple 2 or 3 speed fans for summer operation and variable speed fans for winter ventilation. Two or three speed fans may be required in place of variable speed exhaust fans for winter operation.

d. **Dampers:**

All dampers or air shutters are to be automatically operated opposed blade, tight-closing with less than 2% leakage as tested in accordance with 11.4.2(a)(3) above.

11.4.3 Space Heating.

Space heating requirements are to be based on the Outside Design Temperature for the particular geographic location as tabulated in the ASHRAE Handbook of Fundamentals weather data for heating design requirements.

a. **Primary Heating Equipment**

1) Space heating is to be provided by gas or oil-fired, hot water steel or cast-iron modular boilers, or by a steam-to-hot-water converter for greenhouses served by a central steam plant.

2) Each modular boiler shall meet a minimum efficiency rating (Annual Fuel Utilization Efficiency, AFUE) of 82 percent.

3) Boilers shall be sized to meet the required heat load with piping and pick-up losses included, as per the Hydronic Institute (I=B=R) ratings.

b. **Overhead Air Heating System:**

1) Overhead air heating systems shall be designed to provide approximately two-thirds of the total heating demand as in accordance with ASAE standards and design procedures.

2) Fresh air intake louvers and/or roof caps are to be sized to match the combined air

quantity capacity of the heating and ventilation systems.

3) Each Overhead Air System shall be furnished with a heating kit consisting of unit heaters, baffle plates with air scoops, motor shield and center baffle. All components are to be constructed of corrosion resistant materials suitable for greenhouse installation.

c. **Perimeter Heating:**

1) Perimeter heating shall be provided by fin-tube baseboard radiation located along the outside walls and will supply approximately one-third of the total heating requirements.

2) Perimeter heating shall have a rating of a minimum of 950 Btu/hr per linear foot at 180 degree F supply temperature.

3) All perimeter piping not within the greenhouse envelope and/or located more than 3 feet above ground (except for underbench heating) shall be insulated with suitable insulating materials.

4) All metal-to-metal connectors of dissimilar piping material shall be made with an inert non-conductive material so as to prevent electrolysis.

5) All heating piping systems shall be hydrostatically tested for leaks prior to start up. Test should include a minimum pipe pressure of 2.5 times the normal operating pressure.

6) All overhead piping shall either be located along side walls, or under gutter so as to eliminate unnecessary shading.

d. **Piping Insulation:**

1) All exposed piping shall be insulated with an approved material with a maximum thermal conductivity of .23 Btu-in/hr-sq. ft. - degree F at 70 degree F mean temperature.

2) All valves and fittings shall be fully insulated to the above specification and covered with molded PVC covers.

11.4.4 Space Cooling.

a. **General:**

Space cooling will be provided by pad or unitary evaporative cooling systems. Mechanical cooling may be required to supplement evaporative cooling when a high degree of space temperature control is desired (for Level 3 control only).

b. **Evaporator Pads:**

Evaporative cooling pads shall be 4 or 6 inches thick, constructed of specially treated cellulose paper, or other materials commonly used for greenhouse evaporative cooling pads. All pads are to be securely supported to prevent air flow between pads.

c. **Evaporative Cooling Ancillary Equipment:**

1) All ancillary equipment, such as pumps, valves, floats, etc., shall be included as a packaged system preferably from a single source. All evaporative cooling system piping shall be PVC and gutters are to be aluminum or PVC.

2) Water circulating pumps are to be centrifugal self- priming type with bronze impellers. Pumps shall be complete with discharge gate valve and recirculating gate valves.

d. **Mechanical Cooling:**

Mechanical cooling shall be provided by packaged units sized to meet the cooling load of specialized growing chambers when the evaporative cooling and shading systems alone cannot produce the required space temperatures.

e. **Exhaust Fans:**

All wall exhaust fans are to be comprised of materials that avoid corrosion. All exhaust fans are to be sized to maintain a maximum pressure drop of 0.1 inch water column through the evaporative pad.

1) All wall exhaust fans are to be equipped with two- or three- speed motors of the type commonly used in greenhouse applications. The control of these motors will be in accordance with the "Control Requirements for HVAC Systems" section of this design guide.

2) All exhaust fans shall be equipped with automatically controlled tight closing opposed blade dampers.

3) All motors shall be constructed of NEMA approved materials and designs.

PART 5. CONTROL REQUIREMENTS FOR HVAC SYSTEMS

11.5.1 General.

Three (3) control levels shall be available for each greenhouse prototype -- Minimum Control for Level 1 greenhouses, Moderate Control for Level 2 greenhouses and Fine Control for Level 3 greenhouses. The control level shall be selected depending on permissible variations in environmental conditions:

a. **Level I: Minimum Control**

This control level shall be used when wide temperature and humidity variations are permitted. Greenhouse space temperature during the heating season can vary by 10 to 15 degrees F. Cooling is provided by ventilation air only -- no supplemental cooling (evaporative pads) are included.

b. **Level 2: Moderate Control:**

This control level shall be used when daytime space temperature variations of 5 to 10 degrees are permitted during the heating season. Space cooling shall be supplied by greenhouse ventilation and evaporative cooling systems, and a temperature difference of no more than 8 degrees F shall be permitted from end-to-end along the length of the greenhouse.

c. **Level 3: Fine Control:**

This control level shall be used when precise environmental conditions are required with less than 5 degrees F variations in space temperatures during daytime heating. Space cooling shall be supplied by ventilation air and evaporative cooling systems, and a temperature difference of no more than 5 degree F shall be permitted from end-to-end along the length of the greenhouse. Additional features of Level 3 shall include precise control of outdoor ventilation air, humidity, carbon dioxide levels, solar radiation using shading and other important environmental factors.

11.5.2 Control Components.

a. **Temperature Sensors:**

1) All sensors, controllers, control panels and other control system components and assemblies shall be corrosion resistant and perform satisfactorily within the humid conditions and wide temperature variations that exist in greenhouses.

2) Temperature sensors shall be RTD resistance thermometers or equivalent devices with an accuracy of 0.25 degrees F or better, and a change in accuracy of 0.5 degree F or less over a period of five years after installation.

3) All temperature sensors shall be shielded from solar radiation within aspirating enclosures featuring electric exhaust fans. The temperature sensors shall indicate the average air temperature near the center of the greenhouse at plant level.

b. **Humidity Sensors:**

Humidity sensors shall have an accuracy of (+) or (-) 5% RH, and maintain this accuracy for a period of three years or more. Recalibrations shall be performed every 4 to 6 months.

c. **Control Panels:**

Each greenhouse shall have a separate HVAC control panel for local control of environmental conditions through operation of the heating, ventilating and cooling equipment within the greenhouse. The control panel shall provide a visual display of greenhouse temperature, and shall indicate the operating status of all HVAC equipment.

11.5.3 DAMPERS

Outdoor Air dampers and shutters shall be tight-closing devices with limit switches to prevent greenhouse heating unless the ventilation air dampers are fully closed. The minimum winter ventilation air damper will modulate to control humidity and carbon dioxide levels within the greenhouse.

11.5.4 Level 1 Control.

a. The Level 1 controls for heating and ventilating systems provide for basic control of greenhouse temperatures. A minimum of three (3) stages of control are included: (1) heating stage, (1) dead band around setpoint, and (1) ventilating stage. Specific features of the level 1 control shall be as follows:

1) A (+) or (-) 10 to 15 degrees F temperature range from setpoint without heating or mechanical ventilation operation.

2) Night thermostat setback of greenhouse temperatures by 5 to 10 degrees F.

3) Natural ventilation occurs through ridge and sidewall vents.

4) Electric interlocks to prevent space heating until the sidewall and ridge vents are fully closed.

b. **Sequence of Operation - Level 1:**

1) The central control panel shall receive space temperature information from the greenhouse temperature sensor. Operation of heating and ventilating equipment shall proceed in stages as the temperature of the space varies. A 10 to 15 degree F deadband shall exist without heating or mechanical ventilation.

2) As the temperature increases 5 degrees F above the setpoint, natural ventilation shall start. If, despite the natural ventilation, the temperature increases 5 to 10 degrees F, mechanical ventilation shall be initiated in a single (on-off) stage. Manually operated shading shall be used to prevent severe overheating.

3) If the temperature of the greenhouse decreases more than 10 to 15 degrees below setpoint temperature, the controller shall power the perimeter radiation hot water pump(s) to supply heating. This heating pump shall start and stop in response to the space temperature sensor to maintain the greenhouse setpoint within an adjustable temperature differential of 2 to 4 degrees F. The sequence of operation shall be as follows (SP = Setpoint, Numerical values represents degree F).

Setpoint		
SP (+) or (-) 10 to 15	-	No heating or mechanical ventilation.
10 to 15 Below SP	-	"Hot" water pump shall cycle on-and-off and control valves will modulate to maintain the greenhouse temperature at 10 to 15 degrees F below setpoint temperature.
SP + 5	-	The control panel shall de-energize the heating system, open the sidewall and ridge vents to produce ventilation air flow.

SP + 10 to 15 - The exhaust fan(s) shall be energized. The side vents shall remain open and the ridge vents shall be closed.

4) Night temperature setback shall be initiated by a photocell detector sensing outdoor illumination levels or by a clock timer. When the sensor output decreases at night, the heating temperature setpoint shall decrease by 10 to 20 degrees F. The nighttime setpoint is typically between 40 and 50 degrees F, and shall be field adjusted for varying crop needs.

5) Limit switches on the ridge and sidewall vents must indicate full damper closure before the hot water heating pumps are energized. An alarm shall sound for a call for heat without full vent closure.

6) Summer space temperatures will be equal to or greater than summer design dry bulb temperature and manually applied shading may be required to reduce peak solar heat gain.

11.5.5 Level 2 Control:

a. When more precise heating, ventilating and cooling equipment control is required, a Level 2 control system can be selected. Level 2 incorporates multi-staged control of greenhouse mechanical equipment that maintains space temperatures within 5 degrees F of the heating temperature setpoint. A minimum of eight (8) stages of heating and cooling settings shall be used that include 2- heating, 1- setpoint, and 5- ventilation and cooling stages. The control unit can be a step controller or a computer system that produces the required output signal in response to greenhouse environmental conditions, to operate the ventilating cooling components. Level 2 control shall feature all the functions of Level 1 and shall also include the following control functions:

1) More precise control of space temperatures - within (+) or (-) 5 degrees F of heating setpoint temperature.

2) Automatic reset of hot water temperature based on outdoor air temperature.

3) Two-stage winter ventilation with optional humidity and carbon dioxide control to reduce fuel consumption.

4) Evaporative cooling system.

5) Greenhouse humidity sensing including alarm functions.

6) Optional Features:

(a) Adaptive control features including optimum start/stop, optimum boiler operation and other control functions available for computer control systems.

(b) Solar intensity alarm to indicate the need for shading while maximum cooling is operative.

(c) Carbon dioxide monitoring of greenhouse air including alarm functions, and automatic modulation or positioning of outdoor air dampers.

(d) Humidity monitoring of greenhouse air to automatically operate outdoor air dampers.

(e) Wind and rain sensors to automatically control position of ridge vents.

b. **Sequence of Operation - Level 2:**

1) The central control panel shall receive space temperature information and optionally humidity, carbon dioxide and solar intensity data from greenhouse sensors. Space temperature is the primary control variable that shall regulate, through the central control unit, the operation of the heating, ventilation and cooling equipment. A maximum of (+) or (-) 5 degree F "deadband" temperature range shall exist in which the heating and cooling equipment does not operate. When the greenhouse temperature drops below setpoint the heating equipment shall be energized in two (2) or more stages. When the greenhouse temperature rises above setpoint, the ventilating and cooling equipment shall be energized in five (5) or more stages. A summary of the operating sequence for Level 2 control is included in the following Table that relates the heating or cooling stage to equipment operating status.

The sequence of operation shall be as follows (SP = Setpoint, numerical value represents degrees F).

Setpoint	Stage of Control
SP to SP (+) or (-) 5	Deadband - no heating or cooling
SP - 5	H1 - Minimum heating
SP - 7	H2 - Maximum heating
SP + 5	C1 - Natural ventilation
SP + 7	C2 - Minimum fan ventilation
SP + 9	C3 - Maximum fan ventilation
SP + 11	C4 - Evaporative cooling
SP + 13	Over temperature alarm

2) The equipment control functions shown in the level 2 Control Summary Table shall be enacted as follows:

(a) **Setpoint** equipment operating status:

- Overhead air system is operating to circulate greenhouse air.

- Overhead air system outdoor air damper is closed, but can be automatically opened for short intervals to reduce humidity or to increase daytime Carbon Dioxide levels. Automatic reclosure of outdoor air damper shall be provided by the control system, every 15 minutes.

- The minimum winter exhaust fan shall be electrically interlocked with the overhead air system outdoor air damper, and shall open and close with the overhead air system outdoor air damper.

(b) **H1 - Minimum Heating:**

- Overhead air system shall operate

- Perimeter fin-tube radiation shall operate by:

  - Opening the radiation hot water valve, and
  - Energizing the fin-tube radiation hot water pump

- The overhead air system outdoor air damper and minimum exhaust fan can be automatically operated in response to humidity and carbon dioxide levels as previously described for setpoint operation.

- All other equipment shall be closed or de-energized. Ventilation dampers must be in their full-closed position.

(c) **H2 - Maximum Heating:**

- Stage H1 equipment shall be operational

- Overhead air system outdoor air damper shall be closed except to maintain the desired humidity and carbon dioxide levels.

- Overhead unit heater(s) shall be energized:

  - Hot Water valve on heating coil shall open.

- Hot Water supply pump to heating coils shall be energized.

- Minimum exhaust fan shall operate as needed for humidity and carbon dioxide control - it shall be electrically interlocked with the overhead air system outdoor air damper. (Minimum exhaust fan is smallest fan at low-speed operation or a separate winter exhaust fan.)

(d) **C1 Natural Ventilation:**

- Ridge vents shall be automatically positioned to open in 4 stages (1/4 open, 1/2 open, 3/4 open, fully open) by an electric drive system.

- Sidewall vents shall be automatically positioned to open in 4 stages (1/4 open, 1/2 open, 3/4 open, fully open) by an electric drive system.

- All other HVAC equipment shall be closed or de-energized before ridge and sidewall vents can open.

- The ridge and sidewall vents will open in 1/4 increment with time delays between each stage to prevent rapid cycling of the vent. Optionally, a computer-based control system can provide direct, continuous damper modulation.

(e) **C2 Minimum Fan Ventilation:**

- Overhead Air System shall operate.

- Overhead Air System Outdoor Air Damper shall open.

- Exhaust fan(s) shall operate at low air flow.

- Sidewall vent on wall opposite the exhaust fans shall be automatically positioned to 1/2 open.

(f) **C3 Maximize Fan Ventilation:**

- Overhead air system shall operate.

- Overhead air system outdoor Air Damper shall open.

- Exhaust Fans shall operate at medium air flow.

- Sidewall vents on wall opposite exhaust fans shall be automatically positioned to full-open.

(g) **C4 Maximum Fan Ventilation:**

- Exhaust Fans shall operate at high air flow - (All fans operating at high-speed).

- Sidewall Vents shall be automatically positioned to full-open.

(h) **C5 Evaporative Cooling:**

- Exhaust fans shall operate at maximum air flow - (All Fans operating at high-speed).

- Evaporative pad air damper shall open

- Evaporative pad water pump shall be energized to produce cooling water flow.

- Sidewall vent shall be automatically positioned to full-close position so that all incoming air flows through evaporative cooling pads.

3) The following control system functions shall be included in Level 2:

(a) Two-stage Winter ventilation shall be provided as follows:

Option 1: Two Stage Ventilation

- Stage I shall open the Overhead Air System outdoor air damper to to 1/2-open position, and the winter exhaust fan shall operate at low speed.

- Stage 2 Winter ventilation shall open the overhead Fan-Jet outdoor air damper to full-open position, and the winter exhaust fan shall operate at high speed.

- The system shall automatically operate at Stage I (minimum) ventilation air.

- Greenhouse operators can manually initiate Stage 2 (Maximum) Winter Ventilation to reduce humidity levels or to increase CO_2 levels. The system shall automatically return to Stage I operation (Minimum Winter ventilation) offer a preselected time period of 15 minutes.

- Optionally, humidity and carbon dioxide sensors can select between no ventilation, stage I (minimum) ventilation, and stage 2 (maximum ventilation).

Option 2: Continuous Modulation of Ventilation Air

- Humidity and carbon dioxide sensors will automatically position the outdoor air damper on the overhead air system to produce minimum ventilation air flow rates, while maintaining acceptable humidity and carbon dioxide levels within the greenhouse.

- A modulating outlet damper on the winter exhaust fan will vary the exhaust flow rate to match the ventilation air flow rate.

(b) Continuous measurement of greenhouse Carbon Dioxide concentration shall be provided as an option. The range of the Carbon Dioxide Monitor shall be 0 to 3000 parts per million, with an accuracy of 2 percent of full-scale reading. A digital or analog read-out meter (minimum of 4") and provision for 4-20 ma or 0-1 volt DC output signals shall be provided.

The Carbon Dioxide Meter shall include sampling pump, air filters, high and low CO_2 alarm contacts, and all other components necessary for proper operation in greenhouses.

(c) An optional shading Alarm shall indicate excessive greenhouse temperature while maximum cooling (C5) is operating.

(d) Automatic reset of heating hot water shall be provided based on outdoor air temperature. As the outdoor air temperature increases, the heating hot water temperature shall decrease. An example set-back schedule is as follows:

OUTDOOR AIR TEMPERATURE (degrees F)	**HOT WATER TEMPERATURE (degrees F)**
0	180
55	100

(e) A linear relationship shall exist between the outdoor air temperature and heating hot water supply temperature at intermediate values. The temperature reset schedule shall be adjustable. All required components including hot water temperature sensor(s), shielded outdoor air temperature sensor(s), and hot water temperature controllers shall be provided.

11.5.6 Level 3 Control.

Level 3 can be selected when more precise control of greenhouse environmental conditions is required than is available through Level I or Level 2 operation. Level 3 includes all of the control functions described in Level 1 and Level 2, and shall add the following:

a. Reduced temperature "deadband" and more precise temperature, humidity and carbon dioxide level regulation. Temperature changes shall be 3 degrees F or less.

b. Automatic humidity control by operating ventilation system based on humidistat setpoint. Greenhouse temperature shall be the primary control variable, and greenhouse humidity shall be the secondary control variable. Increased ventilation shall be limited to 15 minutes time intervals to control increased fuel costs during the heating season. The intervals shall be adjustable by the greenhouse operators.

c. Optional automatic fine-tuning of ventilation air dampers during the heating season based on geenhouse Carbon Dioxide levels during daylight hours. The ventilation air dampers shall be fully modulating and shall assume the minimum opening necessary to maintain minimum acceptable Carbon Dioxide levels within the greenhouse. This "carbon dioxide trim" function shall reduce ventilation air to minimum levels for reduced heating energy consumption. The carbon dioxide setpoint, approximately 1000 ppm, shall be adjustable by greenhouse operators, and serve as input to the computer controller to modulate the outdoor air damper positions.

d. Automatic shading controls shall be available as an option to position shade cloths so that greenhouse overheating (above a preselected temperature) is prevented when the HVAC system is operating at maximum cooling. The computer controller shall sense the rise in temperature at maximum cooling and modulate the shade cloth position toward full-closed position.

e. The computer control system shall continually monitor greenhouse temperature, outdoor air temperature, and other important parameters, and record this information in magnetic form such as recording tape, floppy disc, hard disc, or other conventional data storage devices.

PART 6. IRRIGATION SYSTEMS

11.6.1 General.

a. The irrigation system shall be responsive to any of the benching systems used in the greenhouse, including the four growing conditions listed below:

1) Propagation beds
2) Shallow tray, flats or similar small root-media containers
3) Deep bench or ground beds
4) Pots or growing containers

Each of these distinct growing conditions may form a portion of a bench or ground bed or may extend to the entire greenhouse.

b. **Water Supply:**

The water supply shall be equivalent to normal potable water with a flow rate sufficient to provide the requirements of the largest zone of nozzles operating in the system. Any water supply of insufficient pressure shall have a booster pump used to meet the pressure requirements.

c. **Shutoff Valve:**

A manually operated, readily accessible full-flow ball or gate valve shall be used ahead of all system components to facilitate cutoff and maintenance of the system.

d. **Strainer:**

1) An in-line strainer or filter shall be used in the main supply line to provide entrapment of sediment and particles that can inhibit proper operation of solenoids and nozzles.

2) The device shall have a body of brass, aluminum, or plastic, a stainless steel screen or replaceable element filter of 200 mesh size.

3) The in-line strainer shall have a rated flow rate capacity exceeding the flow of the largest zone with less than a 3 psi pressure drop and a safe working pressure exceeding the system maximum pressure.

4) The strainer shall be easily cleaned.

e. **Solenoids:**

1) Solenoids to control the water flow shall be the quick acting type, 24 VAC, normally

closed.

2) Solenoids shall be of brass, plastic or equivalent material and of a size to provide the flow of the line with a pressure drop less than 5% of the line operating pressure.

f. **Vacuum Breaker:**

A vacuum breaker or equal backflow prevention device shall be used downline from the solenoid valve, if required by local codes, to prevent any possible backflow contamination of potable water supplies.

g. **Zones:**

1) Several zones may be established to provide individualized requirements and system sizing as required.

2) Groups of nozzles, distribution lines, a solenoid valve and vacuum breaker (if used) designed for a particular bench or benches and application rate will constitute a zone for control.

h. **Distribution Lines:**

1) The distribution line(s) shall be of working pressure exceeding the supply maximum and a size to provide the flow rate for not exceeding 10% of the input operating pressure.

2) Acceptable materials include but are not limited to PVC, PE, and copper.

11.6.2 Propagation Beds.

a. Propagation beds enable cuttings from existing plants to be nurtured until a root system is established that will sustain the new plant in a normal growing environment. Propagation beds require a micro-environment of high humidity, a film of on the leaf surface and full sunlight. This micro-environment is provided by misting.

b. A misting system consists of a relative high pressure water source, nozzles that produce a fine mist, and controls that regulate the frequency and duration of misting. Figure 11-15 illustrates the main components of a misting system and propagation bed.

c. **Water Supply:**

Water supply shall be as specified in paragraph 11.6.1(b) with a pressure of 4.0 to 125 psi.

d. **Shut off Valve:**

A shutoff valve as specified in paragraph 11.6.1(c) shall be provided.

e. **Strainer:**

An in-line strainer as specified in paragraph 11.6.1(d) shall be provided.

f. **Nozzles:**

1) Nozzles shall be a 'misting' or 'fogger' type that produce a fine mist at 40-125 psi pressure range. Nozzles output shall be of 0.02 to 0.15 gpm.

2) Nozzles shall provide as uniformly as possible a mist over the cuttings from edge to edge of the bench and along its length. Nozzles shall be arranged in an overlapping pattern.

3) The nozzles shall operate on a vertical riser above the bed or under an overhead pipe as illustrated in Figure 1 depending on the specific greenhouse application.

4) Overhead pipe shall have a pressure release valve in the lowest part of the pipe to drain the pipe when cut off, thus preventing spots of water drip from the nozzles. The nozzle height above the plants and spacing along the line shall be per the manufacturer's specifications for the nozzle design used.

5) The nozzle design shall provide for easy cleaning and un-clogging maintenance by the user.

g. **Distribution Line:**

1) Distribution line shall be provided as specified in paragraph 11.6.1(h).

2) The distribution lines shall be supported as necessary to keep sag between the supports less than one-half the line diameter.

h. **Solenoids:**

Solenoids shall be provided as specified in paragraph 11.6.1(e).

i. **Vacuum Breaker:**

Vacuum breaker shall be as specified in paragraph 11.6.1(f).

j. **Zones:**

Refer as specified in paragraph 11.6.1(g).

k. **Controls:**

Minimum controls for the misting system shall consist of a 24 hour cycle timer mechanism capable of manually setting a minimum of 5 or 6 seconds up to 30 seconds 'On' time per 10 minute period, and tapering to a minimum of 5 seconds 'ON' for any one hour period throughout the 24 hour cycle.

l. **Optional Controls:**

An "Artificial Leaf" or equivalent sensor device may be used to activate a solenoid valve and connected misting line to provide automatic ON-OFF operation if such devices ensure reliable control of the system.

m. **Bed Protection:**

Propagation beds located in the vicinity of other greenhouse operations with low humidity and/or excessive air movement that can cause rapid drying or distort the mist application may need a protective hood of clear plastic film draped over a non-corrosive framework to shield the mist yet allow suitable temperature uniformity for the bed.

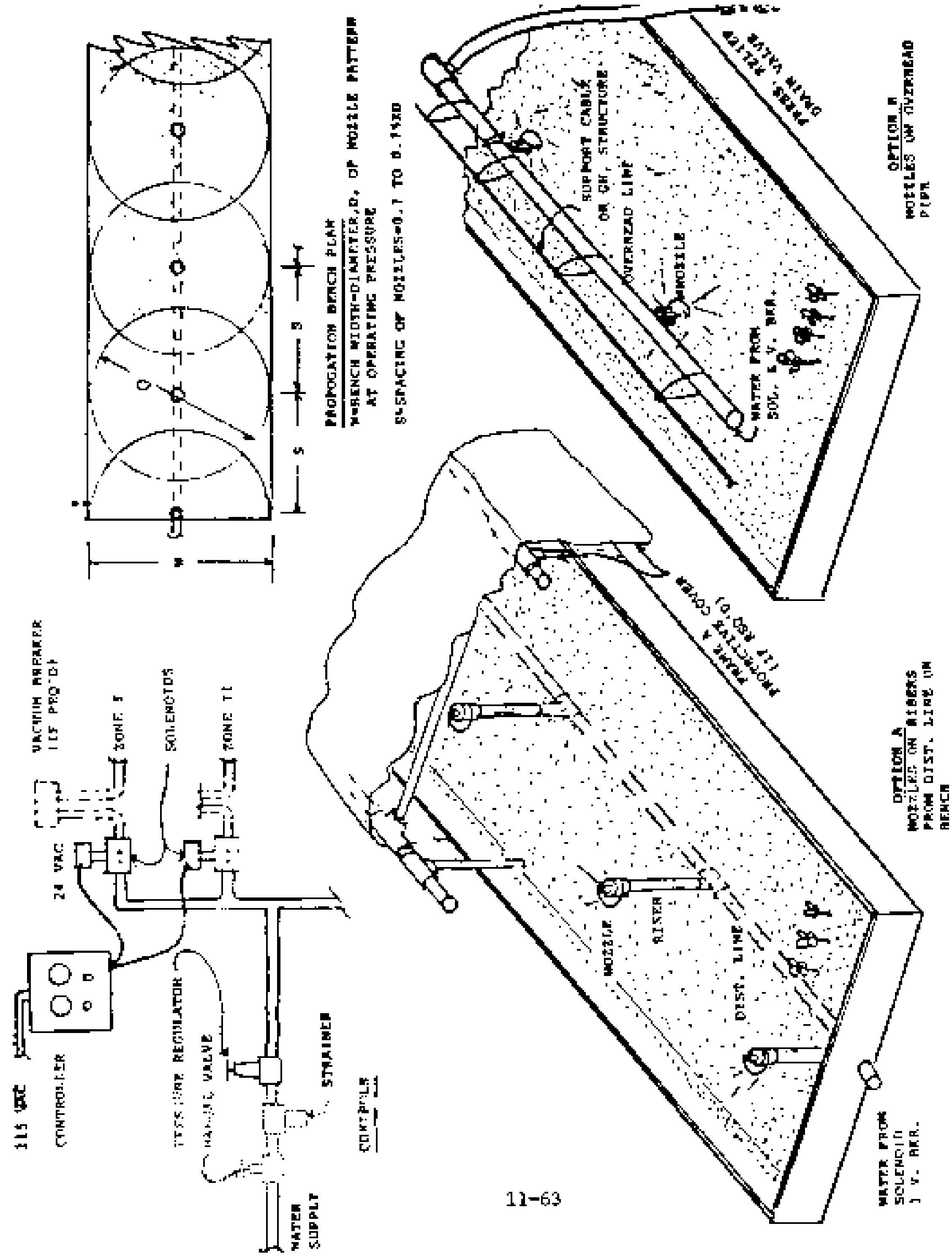


FIGURE 11-15 ILLUSTRATION OF MISTING SYSTEM AND PROPAGATION BED

11-63

11.6.3 Shallow Trays, Flats Or Similar Small Root-Media Containers:

a. Shallow trays, flats and similar germinating or early growth containers have characteristics of low water holding capacity and high evapotranspiration rates which necessitate frequent low-volume watering cycles.

b. The mist propagation system described above may be used for these applications with a longer ON period per watering and less frequent periods to provide the required root-media moisture content.

c. Alternate spray or sprinkler nozzle systems with larger droplet sizes may also be used. Specifications for this latter methods follow. Figure 11-16 illustrates the main components of the spray or sprinkler nozzle system with bench level distribution lines.

d. **Water Supply:**

The water supply shall be as specified in paragraph 11.6.1(b) with a pressure of 40 to 80 psi.

e. **Shutoff Valve:**

Shutoff valve shall be provided as specified in paragraph 11.6.1(c).

f. **Strainer:**

An in-line strainer or filter as specified in paragraph 11.6.1(d) shall be used, except that a 100 mesh screen or filter may be used alternately.

g. **Nozzles:**

Nozzles shall be a spraying or sprinkler type that produce a uniform watering pattern at 40-80 psi. Nozzles shall have an output of 0.10 to 0.50 gpm. The nozzles shall operate on a vertical riser or under an overhead pipe as illustrated in Figure 2 depending on the specific greenhouse application. The nozzle height above the plants and spacing along the line shall be per the manufacturer's specifications for the nozzle design used so as to provide as uniformly as possible water application from edge to edge of the bench and along its length. Nozzles are generally arranged in an overlapping pattern.

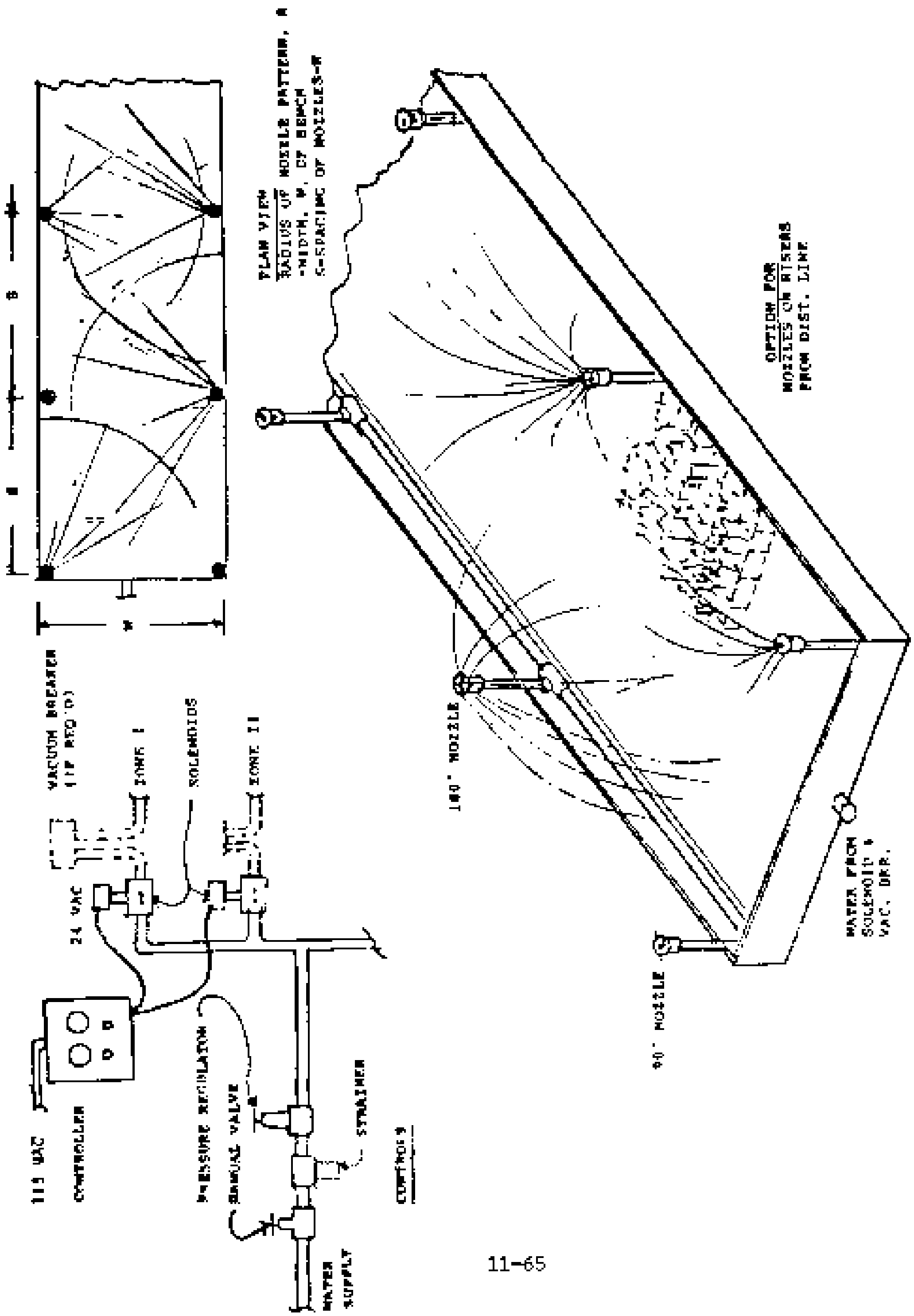


FIGURE 11-16 ILLUSTRATION OF SPRAYING NOZZLES FOR FLATS AND SHALLOW BENCH

h. **Distribution Line:**

Distribution line shall be as specified in paragraph 11.6.1(h) with a pressure release drain valve and line used to drain the distribution lines at shutoff.

i. **Solenoids:**

Solenoids shall be provided as specified in paragraph 11.6.1(e)

j. **Vacuum breaker:**

Vacuum breaker shall be provided as specified in paragraph 11.6.1(f).

k. **Zones:**

Refer as specified in paragraph 11.6.1(g).

l. **Controls:**

Minimum controls for the sprinkler watering system shall consist of a 24 hour cycle timer mechanism capable of manually setting 10 minutes ON per 60 minute interval tapering to a minimum of 1 minute ON for any one hour period throughout the 24 hour cycle.

11.6.4 Deep Bench Or Ground Beds.

a. **Watering System:** Deep bench (over 4 inches of media) or ground beds have greater water holding and moisture migration characteristics than trays and can utilize a watering system that either wets the foliage or keeps the foliage dry during watering applications.

b. **The spray or sprinkler system:** Any of these systems can be readily utilized for a 'wet' foliage system whereas optional 'trickle tube' systems described in 11.6.4(g) can be used to maintain dry foliage, hence less likely disease spread during watering. **Figure 11-17** illustrates a trickle tube system as further defined below.

c. **Water Supply:**

Water supply provided as specified in paragraph 11.6.1(b) with a pressure 5 to 15 psi.

d. **Shutoff Valve:**

Shutoff valve shall be provided as specified in paragraph 11.6.1.(c).

e. **Pressure Regulator:**

A pressure regulator shall reduce normal water supply pressure to the required 5 to 15 psi for the trickle tube system. The pressure regulator shall be capable of operating at the main supply line incoming pressure and provide the required flow for a zone of trickle tube at the pressure required by the trickle tubes with less than a 5% variation in flow control.

f. **Strainer:**

An in-line strainer or filter as specified in paragraph 11.6.1(d) shall be used.

g. **Trickle Tubes:**

Trickle tubes shall be the two-chamber type or 4- or 9- mil plastic with outlet spacing 4 x 20 or 4 x 24 and an output of approximately 1.5 gpm per 100 ft. of tube.

h. **Distribution, Header and Lateral Lines:**

Distribution lines shall be as specified in paragraph 11.6.1(h) with a pressure release drain valve.

i. **Solenoids:**

Solenoids shall be provided as specified in paragraph 11.6.1(e).

j. **Vacuum Breaker:**

Vacuum breakers shall be as specified in paragraph 11.6.1(f)

k. **Zones:**

Groups of trickle tubes, distribution lines, a solenoid valve and vacuum breaker shall constitute a zone as specified in paragraph 11.6.1(g)

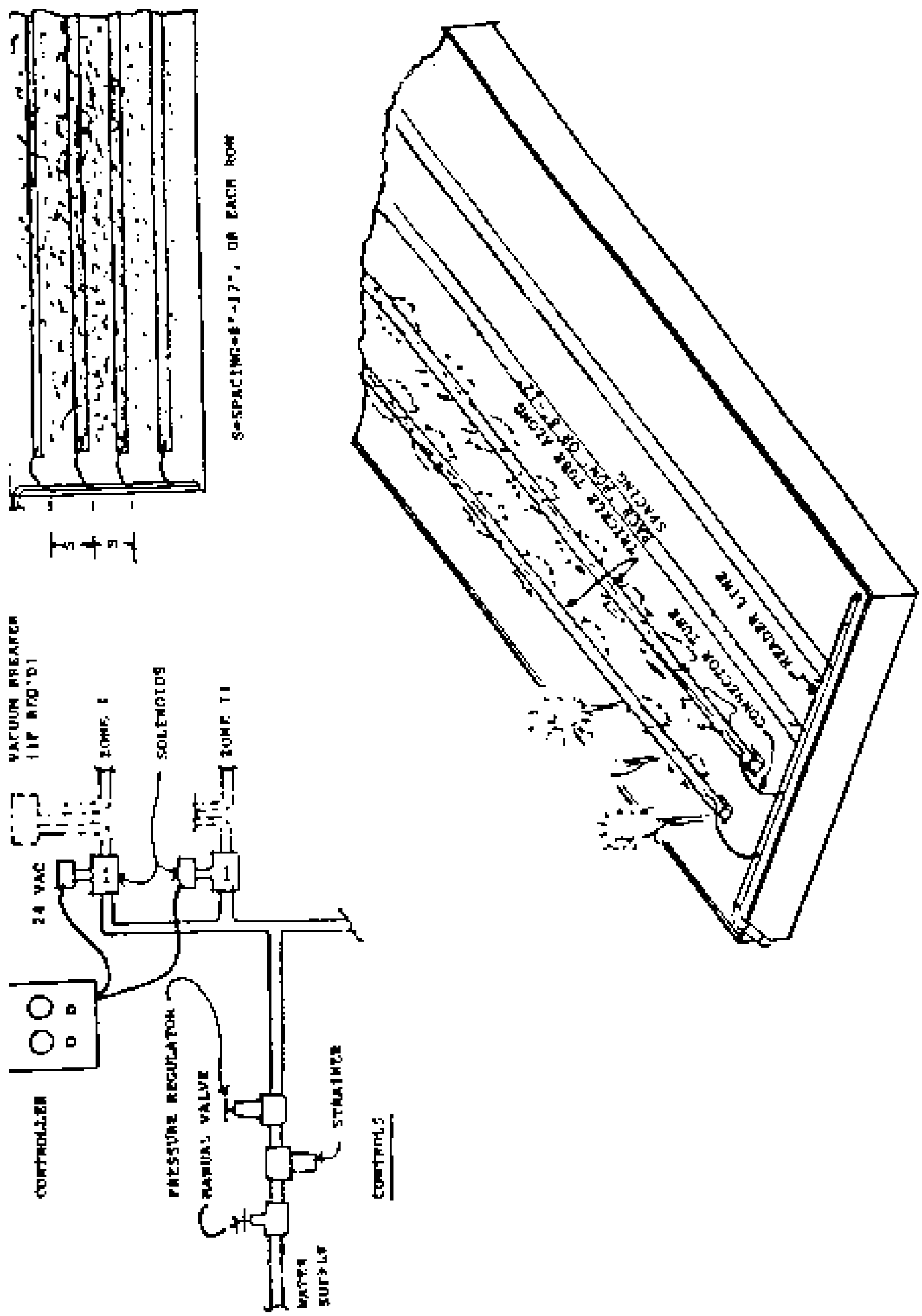


FIGURE 11-17 TRICKLE-TUBE SYSTEM FOR DEEP BENCH OR GROUND BEDS

l. **Controls:**

Minimum controls for the trickle tube system shall consist of a 7 day cycle timer mechanism capable of manually setting 0.5 to 4.0 hours ON during a selected day with non-selected days skipped. Each zone shall be controllable independently.

11.6.5 Pots and Large Growing Containers.

a. **Pots or growing containers:** If larger than 4-6 inches in typical width and height, they have characteristics of good water holding capacity with medium evapotranspiration rates.

b. **Watering methods:** Primarily spray or sprinkler systems where the foliage can be wet or a single watering micro-tube per pot for dry foliage requirements. The single-tube-per-pot system involves special micro-size tubes with one end placed on the pot's surface and the other end inserted as a friction fit in a PVC or PE main or header line operating at low pressure - around 4-5 psi. **Figure 11-18** illustrates these alternatives.

c. **Water Supply:**

Water supply shall be as specified in paragraph 11.6.1(b) with a pressure of 4-5 psi.

d. **Shutoff Valve:**

Shutoff valve shall be provided as specified in paragraph 11.6.1(c).

e. **Pressure Regulator:**

1) Pressure regulator: It shall reduce normal water supply pressure to the required 4-5 psi or the micro-tube system.

2) Pressure regulator: It shall be capable of operating at the main supply line incoming pressure and provide the required flow for a zone of trickle tube at the pressure required by the tubes with less than a 5% variation in flow control.

f. **Strainer:**

An in-line strainer or filter as specified in paragraph 11.6.1(d) shall be used.

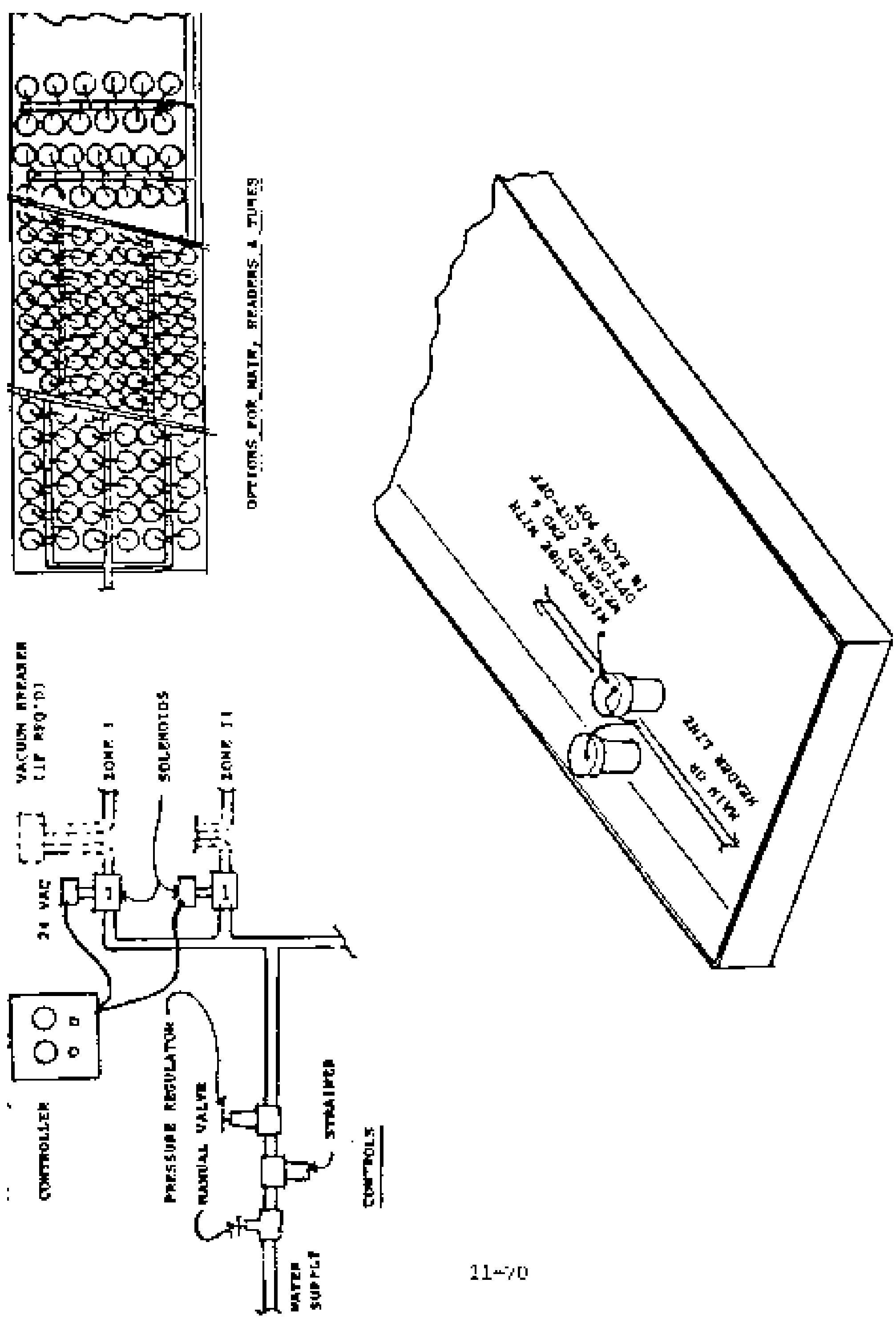


FIGURE 11-18 INDIVIDUAL MICRO-TUBE SYSTEM FOR POTS

g. **Tubes:**

Current commercial 'Leader' type tubes shall be used. Available sizes range from 0.036 to 0.076 inch ID, 12 to 72 inches long, and 0.128 inches OD with a flow of 0.01 to 0.12 gpm at 4 psi.

h. **Distribution, Header and Lateral Lines:**

Distribution lines shall be provided as specified in paragraph 11.6.1(h) with a pressure release drain valve.

i. **Solenoids:**

Solenoids shall be provided as specified in paragraph 11.6.1(e).

j. **Vacuum Breaker:**

Vacuum breaker shall be provided as specified in paragraph 11.6.1(f).

k. **Zones:**

Groups of micro-tubes distribution lines, a solenoid valve and vacuum breaker shall constitute a zone as specified in paragraph 11.6.1(g).

l. **Controls:**

Minimum controls for the micro-tube system shall consist of a 7 day cycle timer mechanism capable of manually setting 0.5 to 4.0 hours "ON" during a selected day with non-selected days skipped. Each zone shall be controllable independently.

11.6.6 Decalcification Of Potable Or Irrigation Water.

a. **Decalcification:** Decalcification (water softening) of potable or irrigation water requires four conditions to be considered:

1) Hardness of water supply (grains per gallon)

2) Level of hardness permissible for plant use

3) Quantity of water required per unit of time

4) Side effects of secondary chemical build-up

b. Water softening exchanges calcium (Ca++) and magnesium ions (Mg++) with sodium ions (Na+) on the surface of an ion exchange resin in a tank. Water flowing through the tank is softened as long as exchangeable sodium ions are still available. Softened water contains increased sodium and, thus, could be detrimental to plant growth, especially with salt build-up over time. Water with less than 60 mg/liter (3.5 grains per gallon) hardness is generally not softened because this small amount does not cause unreasonable damage to fixtures. Commercial tank-type equipment is generally used for water softening. Mixed-bed ion exchangers, sometimes called deionizers, remove all or selected minerals such as calcium, magnesium, sulfate and nitrate. Reverse osmosis equipment likewise can remove almost all minerals.

c. **Water Softeners:**

1) Softeners are automatic, semi-automatic, or manual. Each type is made in several sizes and is rated on the amount of hardness that can be removed before regeneration is necessary.

2) Fully automatic softeners regenerate on a preset schedule and return to service automatically. Regeneration is usually started by a time clock; some units are started by meters or hardness detectors.

3) Semi-automatic softeners have automatic controls except for the start of regeneration.

4) Manual softeners require the manual operation of one or more valves to control backwashing, brining, and rinsing.

d. **Sizing:**

1) The softener size to install depends on the amount of hardness and other dissolved minerals such as iron in the water, pump capacity (the available flow rate for backwashing), water use per day, and the desired time between regenerations.

2) A softener rated at 20,000 grains of hardness exchange capacity softens 1000 gal of water with 20 grains/gal between regenerations.

PART 7. ELECTRICAL

11.7.1 Basic Materials and Methods.

All electrical wiring in the greenhouse shall be designed for accommodating additional circuits in the future. Lighting circuits shall provide a minimum of 27 watts/sq. ft.

a. **Raceways:**

1) Wiring for lighting purposes shall be placed in raceways suspended overhead, at eave height, above each circulation alley.

2) Each raceway shall be equipped with on-off switches, at least one per compartment and at least two per greenhouse (one in the proximity of each gable). Each raceway shall be equipped with outlets located at 10 ft.- 12 ft. on centers.

3) Raceways shall be made of aluminum.

b. **Conduits:**

Conduits shall be as specified in the National Electrical Code.

11.7.2 Lighting.

Greenhouse electrical systems shall accommodate any lighting system listed below or combination thereof:

Incandescent
Fluorescent
Metal Halide
Mercury Vapor
High and Low Pressure Sodium

CHAPTER 12. DRAFTING STANDARDS
PART 1. GENERAL

12.1.1 General: These standards were developed for designers and drafters to ensure clear, uniform design drawings and illustrations. Primary consideration is also given to the reproduction processes, equipment, and techniques utilized later. Strict adherence to these standards is essential.

12.1.2 Drawing Media: All drawings will be prepared in pencil on mylar supplied by ARS.

12.1.3 Reproduction/Reduction: All work will be prepared for printing at one-half size reduction unless otherwise instructed. Character definition shall be of such quality that drawings may be reduced to35 mm microfilm and blown back full size by microreproduction process without showing evidence of filled-in loops, or a running together of characters and/or lines.

12.1.4 Lettering: Generally, lettering shall be vertical, all caps, single stroke commercial Gothic style, 1/8 inch minimum height, as illustrated later. The lettering may be produced either freehand, by the use of mechanical lettering instruments, or any of the newer mechanical-electrical lettering devices if they otherwise conform to the height and general style requirements. Special guidance for symbol and topographic mapping notations are treated separately in this volume. Titles and sub-titles within the body of the drawing, graphic scales, title and revision block information, and certain other items must be mechanically lettered as described later.

12.1.5 Drawing Scales: Scales should be selected to avoid overcrowding and allow for half-size reductions. Where this is not practicable, congested areas should be pulled out and enlarged to a suitable scale. A graphic scale will be shown on every drawing or for every portion of the drawing of a different scale. The graphic scale is normally centered directly under the title of the view and need not be repeated on that sheet if the same scale reoccurs.

12.1.6 Line Weights: During the initial selection of line weights, important features and outlines should be more prominently depicted than those of secondary or unrelated features. Line weights are described and delineated later.

12.1.7 Uniformity: When making alterations or additions to existing drawings, special care should be exercised to follow the same style and size lettering, as well as other conventions on the drawing(s) in the interest of uniformity.

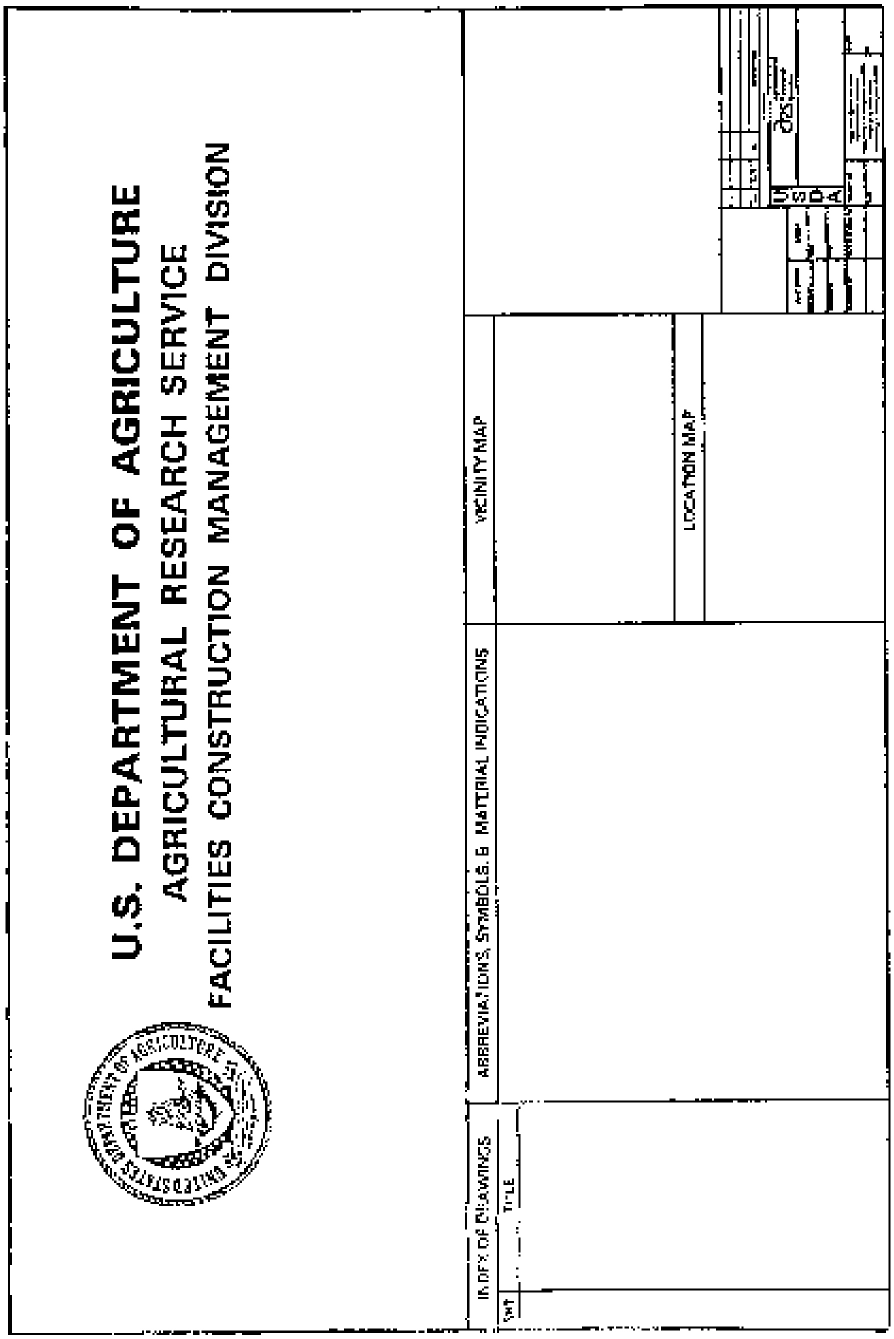
12.1.8 Computer Aided Design and Drafting (CADD): CADD systems may be utilized for drafting production. However, the computer-generated drawings should exhibit the same general high quality standards specified for manual drafting (i.e., ink pen-plotting, clarity, appropriate lettering size and style, etc.)

12.1.9 Miscellaneous: Appliques ("stick-ons"), shading, screening, and other techniques not specifically authorized herein are not permitted. These techniques are not compatible with our filing and/or reproduction process.

PART 2. STANDARDS

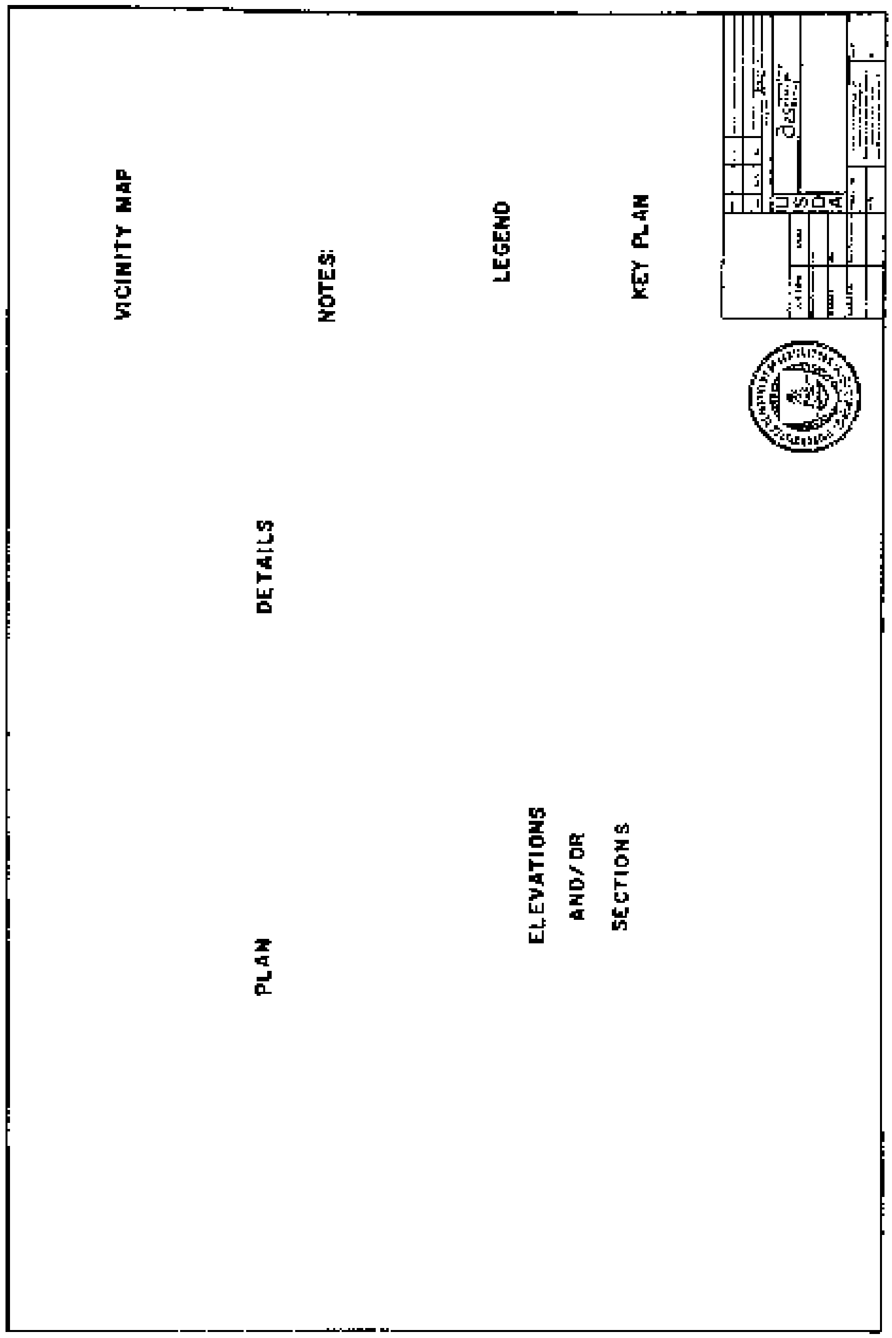
(refer to pages 302 through 350)

COVER - INDEX SHEET FORMAT



12-3

SHEET LAYOUT FORMAT



NOTES:
1. LOCATE GENERAL NOTES, LEGEND, VICINITY MAP, KEY PLAN, AND SURVEY DATA WHEN APPLICABLE ABOVE TITLE BLOCK.
2. LAYOUT MAY VARY WITH SHEET CONTENT.

12-4

CONVENTIONS
LINES

LINE CONVENTIONS AND WEIGHTS:

CENTER LINE	00 PEN
DIMENSION	00 PEN
LEADER	00 PEN
BREAK	00 PEN
PHANTOM	00 PEN
EXISTING FEATURE	00 PEN
HIDDEN	0 PEN
VISIBLE (OBJECT OUTLINE)	* 1 PEN OR 2 PEN
PRIMARY FEATURE (ELEC., PLUM., ETC.)	2 PEN
PRIMARY FEATURE (REINF.)	3 PEN

* CONSULT SUPERVISOR OR CHIEF, DRAFTING SECTION FOR CORRECT APPLICATION

PEN SIZES:

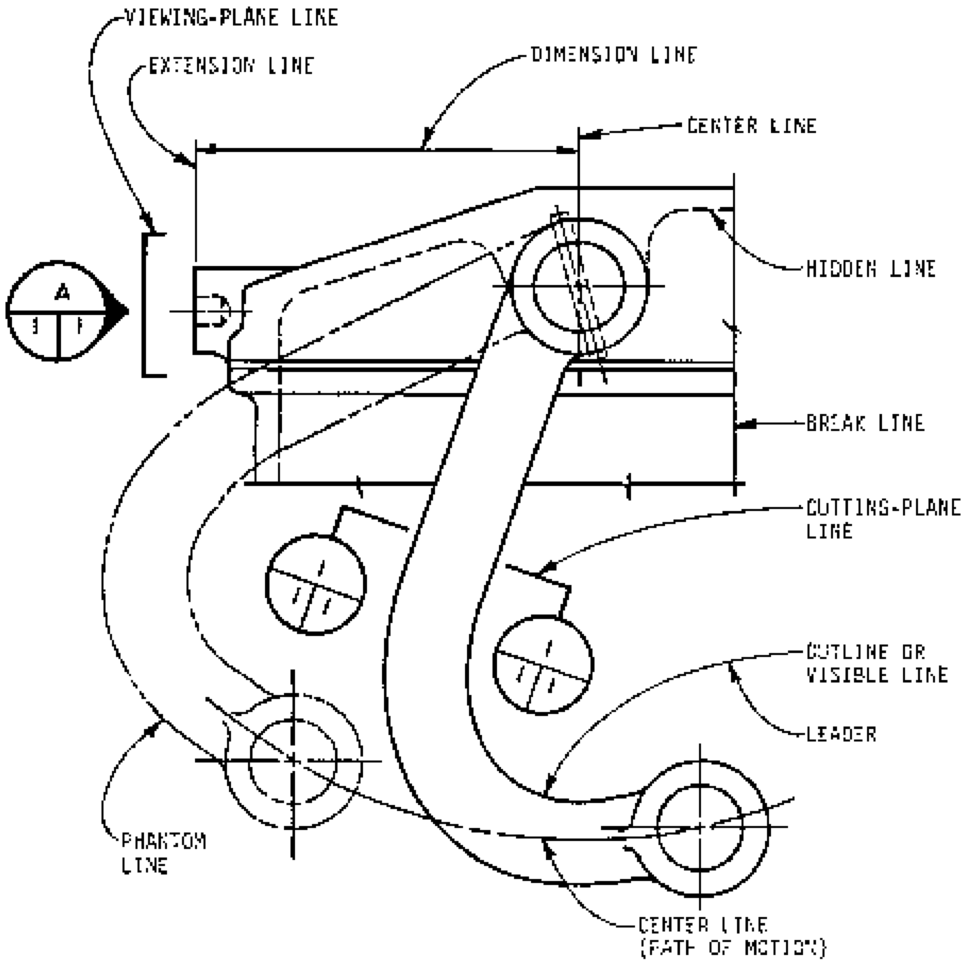
NO. 000 00 0 1 2 3 4 5 6 7 8 9 10 12 14

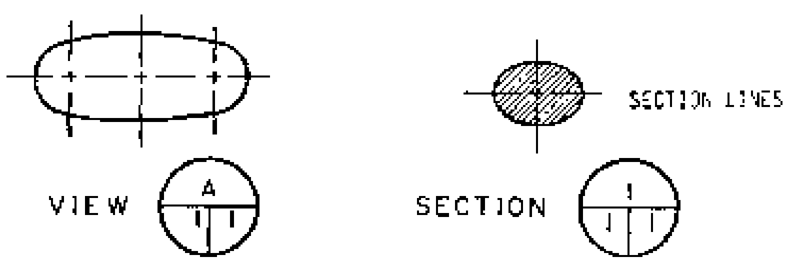
NOTE:

LETTERING AS DESCRIBED IN GENERAL INSTRUCTIONS IS ACCEPTABLE.

12-5

CONVENTIONS
LINES- ILLUSTRATED USE

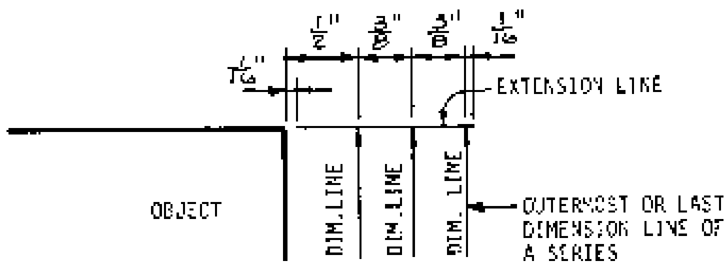




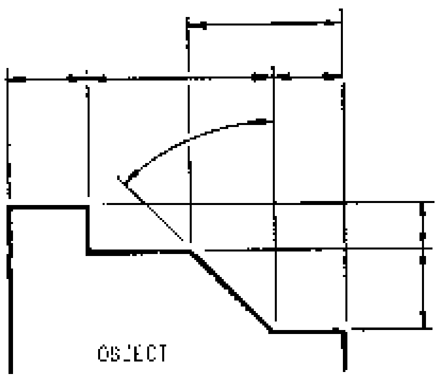
12-6

CONVENTIONS
DIMENSIONING

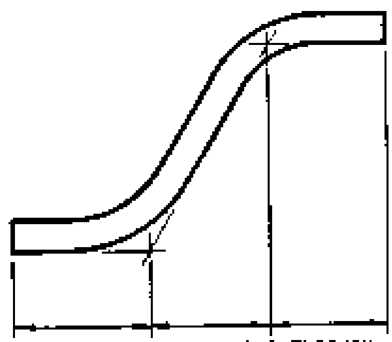
DIMENSION AND EXTENSION LINE SPACING:



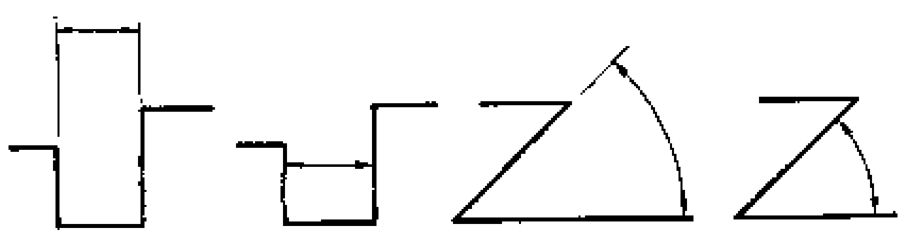
USE OF EXTENSION LINE:



EXTENSION LINES SHOULD BE BROKEN WHEN CROSSING DIMENSION LINES, AND UNBROKEN WHEN CROSSING OBJECT LINES OR OTHER EXTENSION LINES.



EXTENSION LINES PASS THROUGH POINT OF INTERSECTION CREATED BY EXTENDING THE OBJECT OUT-LINES OR CENTER LINE.



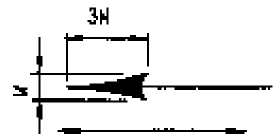
RECOMMENDED NOT RECOMMENDED RECOMMENDED NOT RECOMMENDED

12-7

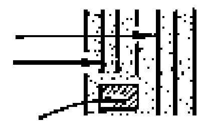
CONVENTIONS
DIMENSIONING – LEADERS AND ARROWS

ARROWS:

USE SMOOTH CURVES
FOR LEADER LINES

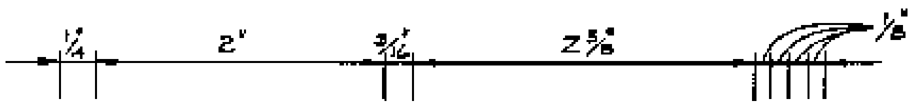


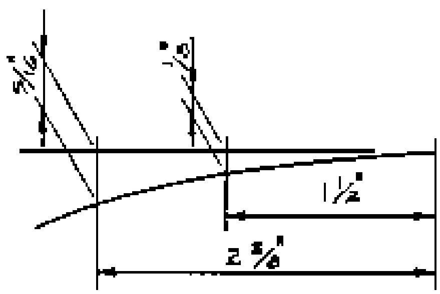
USE THIS TYPE ARROWHEAD



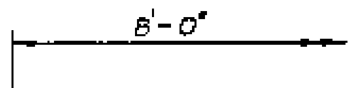
LEAVE CLEAR SPACE
AROUND ARROWHEAD

GENERAL:

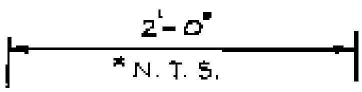




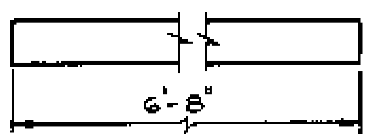
DIMENSIONING IN CROWDED AREAS



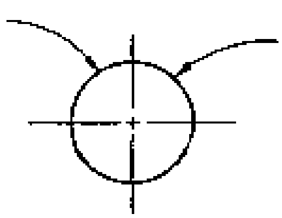
FOR CONTINUATION



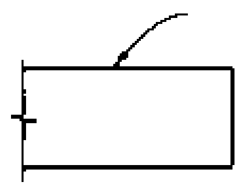
* NOT TO SCALE
USE WHEN REQUIRED



RECOMMENDED



LEADERS TO CIRCLES SHALL BE
IN RADIAL DIRECTIONS

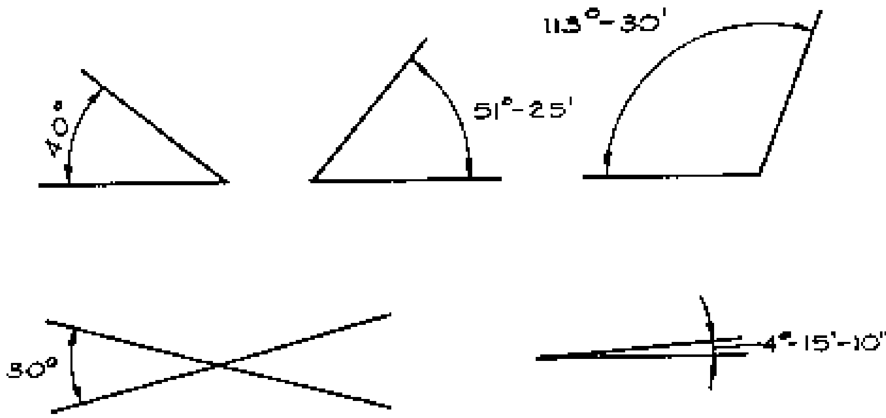


LEADERS SHALL BE NEAR PERPENDICULAR TO OBJECT SURFACE

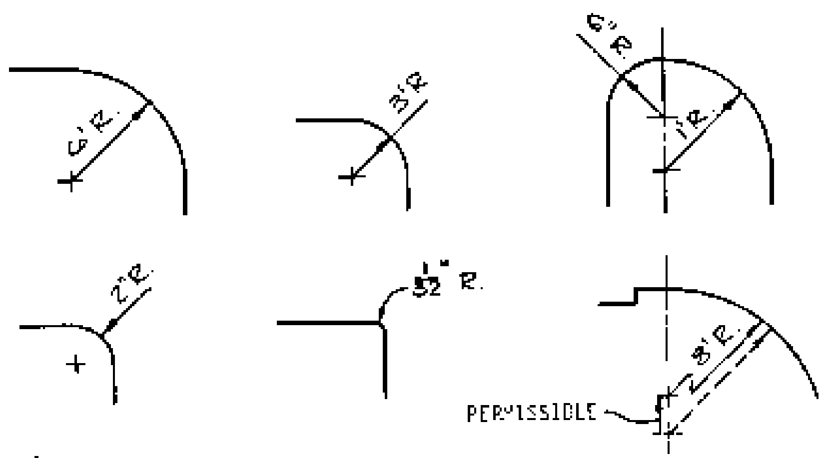
CONVENTIONS

DIMENSIONING - ANGLES, RADII AND CHAMFERS

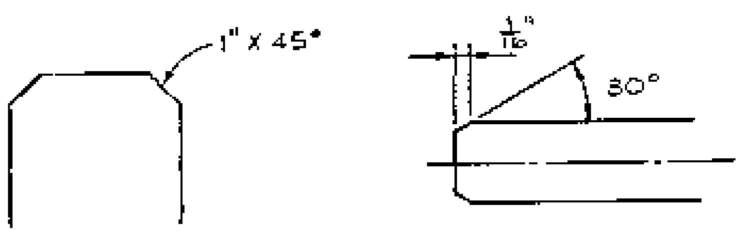
ANGLES:



RADII:

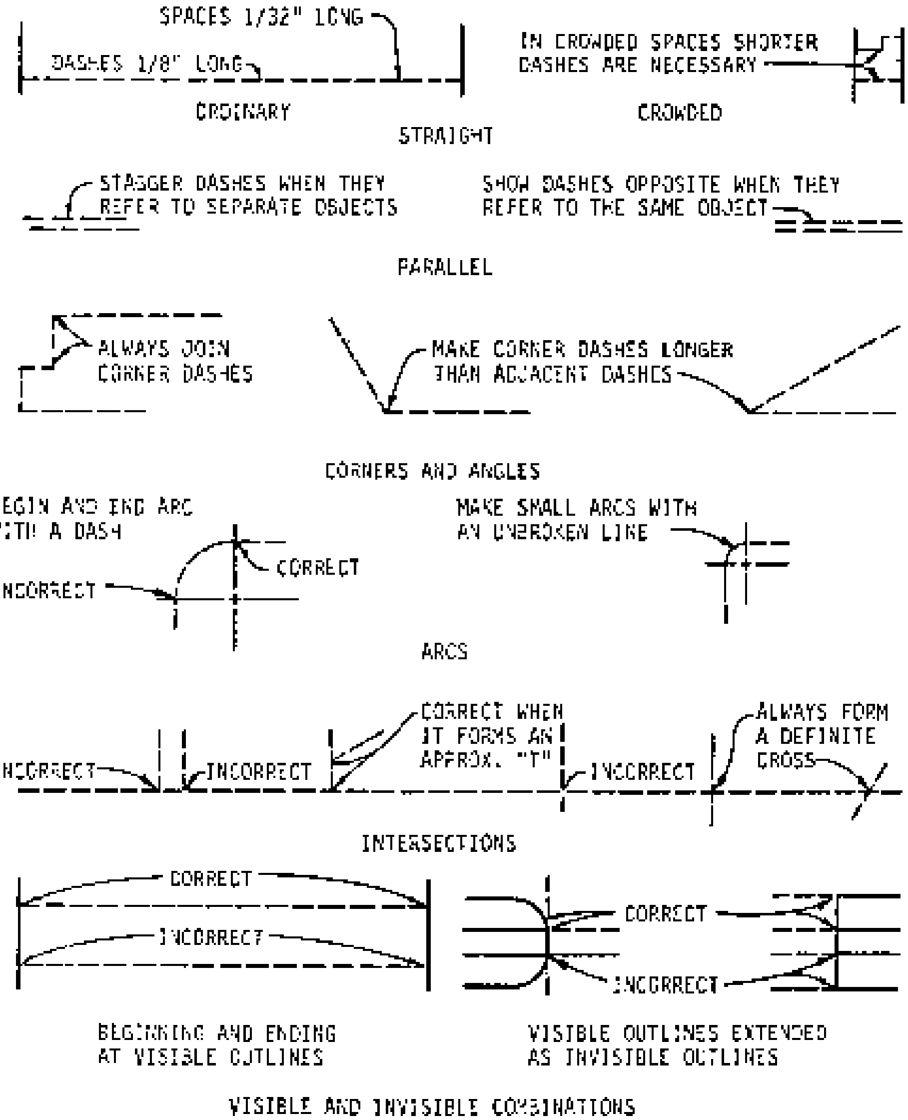


CHAMFERS:



CONVENTIONS
INVISIBLE OUTLINES

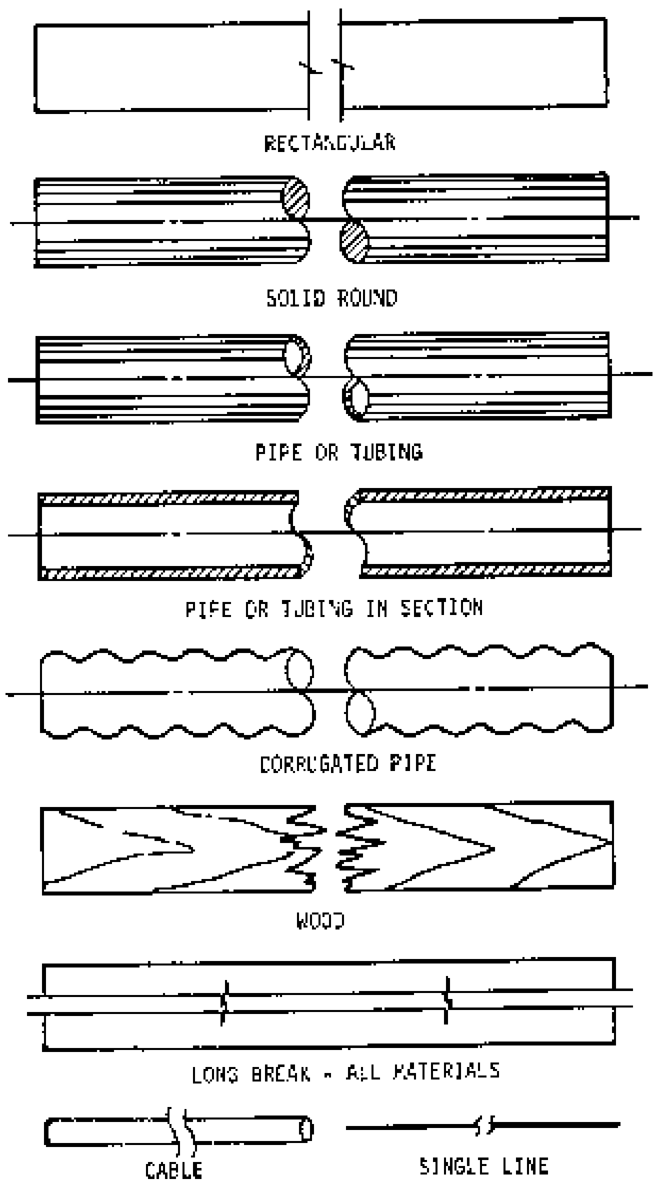
EXAMPLES: LINE WIDTHS, LENGTHS AND SPACES MAY VARY ACCORDING TO SCALE



NOTE:

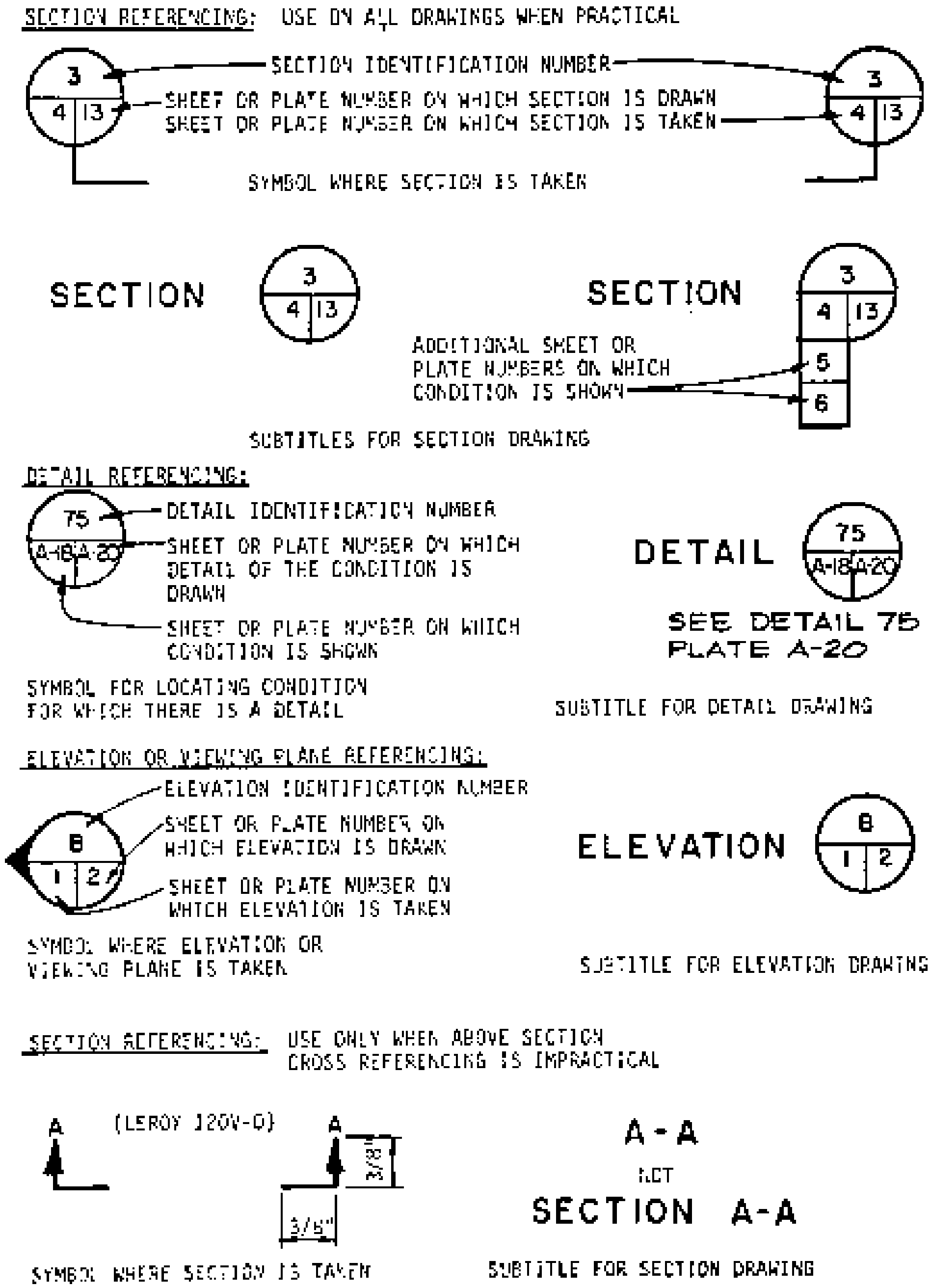
SINCE INVISIBLE OUTLINES ARE DIFFICULT TO READ, PARTICULAR ATTENTION SHOULD BE GIVEN TO THE UNIFORMITY OF LENGTHS OF DASHES AND SPACES AND TO THE CORRECT BEGINNING, ENDING AND JOINING OF DASHES. THE EXAMPLES ARE SELF-EXPLANATORY AND SHOULD BE CAREFULLY FOLLOWED.

CONVENTIONS
BREAKS



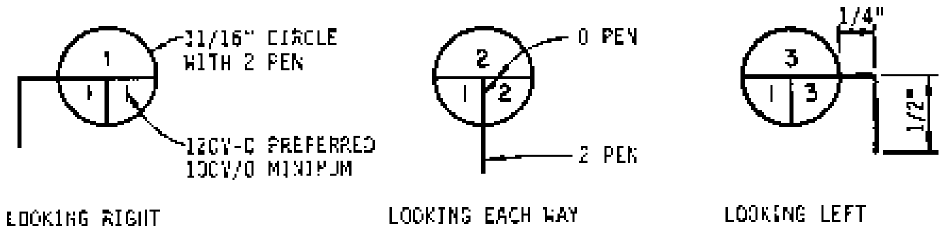
12-11

CONVENTIONS
SECTION, DETAIL AND ELEVATION CROSS REFERENCING

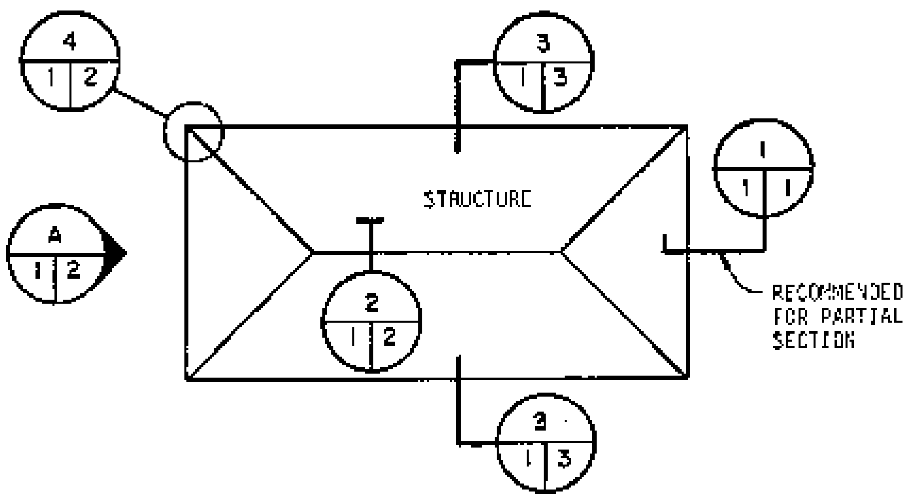


CONVENTIONS
CROSS REFERENCING ILLUSTRATIONS

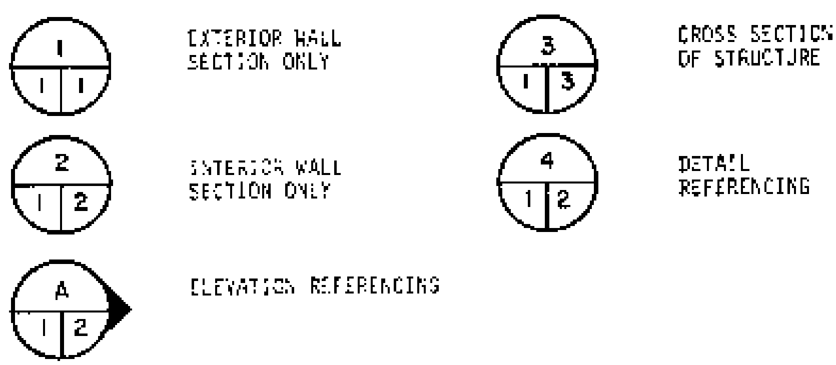
SYMBOL SIZE AND DIRECTION:



EXAMPLE:



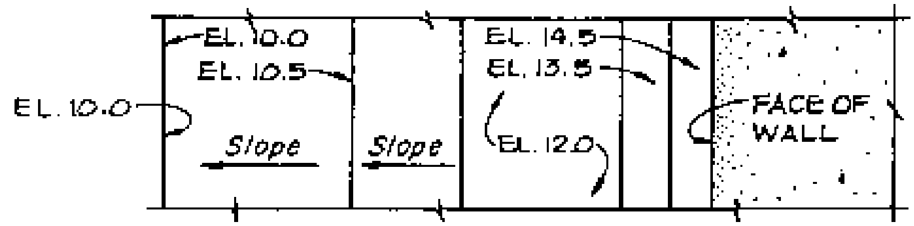
EXPLANATION



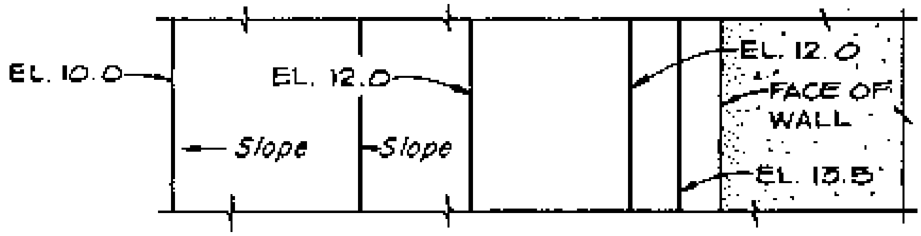
12-13

CONVENTIONS
ELEVATION (HEIGHT) INDICATIONS

PLAN:

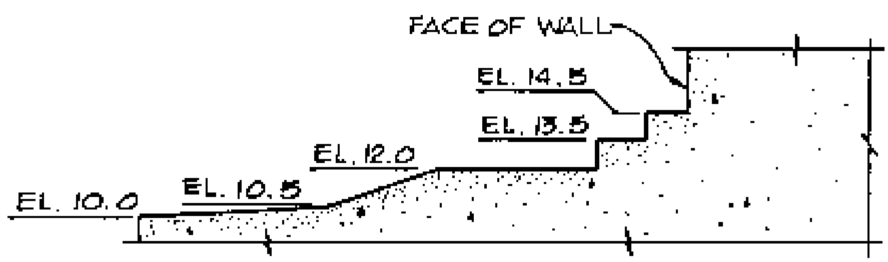


CORRECT METHOD

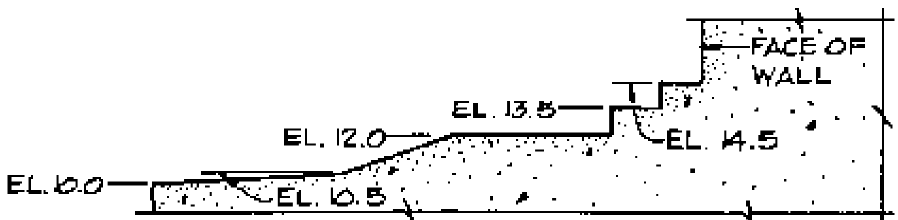


INCORRECT METHOD

SECTION:



CORRECT METHOD

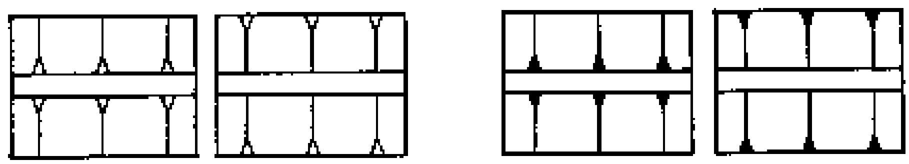


INCORRECT METHOD

12-14

CONVENTIONS
SLOPES AND GRADES

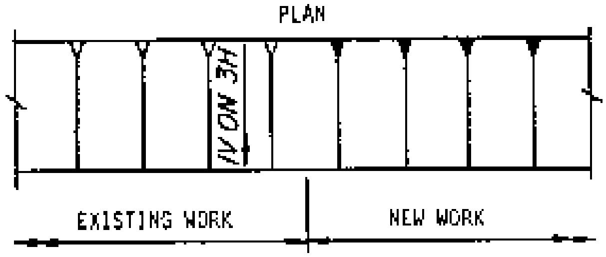
SLOPES: APPLICABLE TO EMBANKMENTS OR EXCAVATIONS



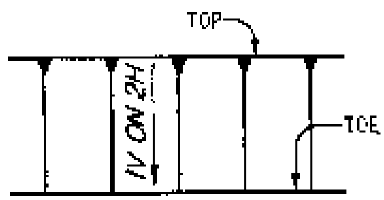
FILL CUT FILL CUT

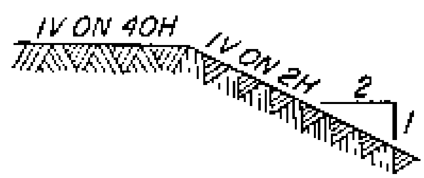
EXISTING NEW

PLAN



PLAN OR ELEVATION



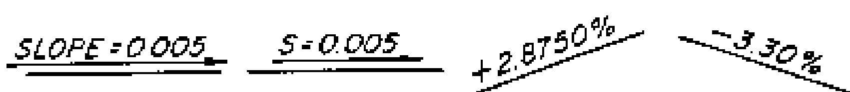


VARY SPACING TO SUIT SCALE OF DRAWING

PLAN OR ELEVATION SECTION OR ELEVATION

GIVE SLOPE AS A RATIO OF THE VERTICAL RISE ON A HORIZONTAL DISTANCE

GRADES: APPLICABLE TO ROADS AND DRAINAGE DITCHES

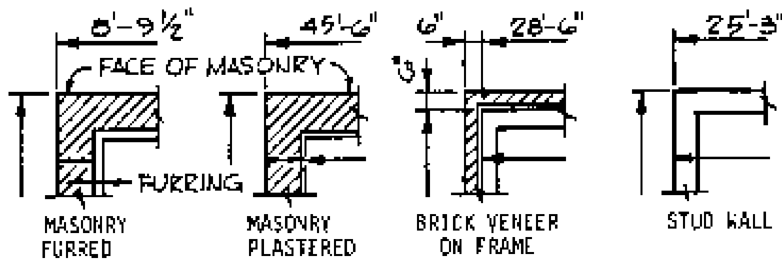


(WHEN CROWDED)

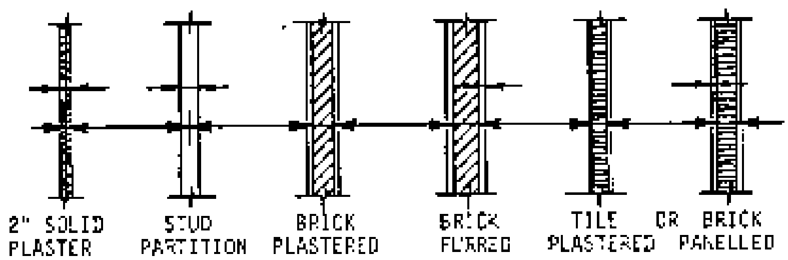
SECTION OR PROFILE

CONVENTIONS
ARCHITECTURAL

DIMENSIONING WALLS AND PARTITIONS:

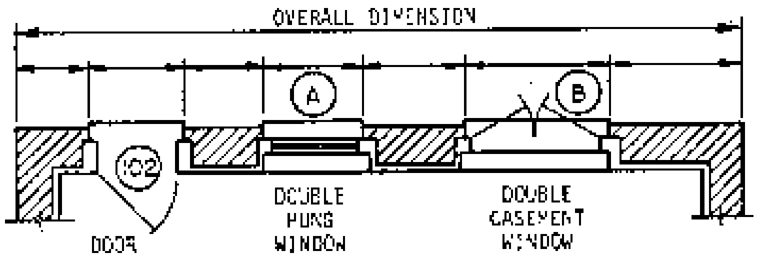


EXTERIOR WALLS

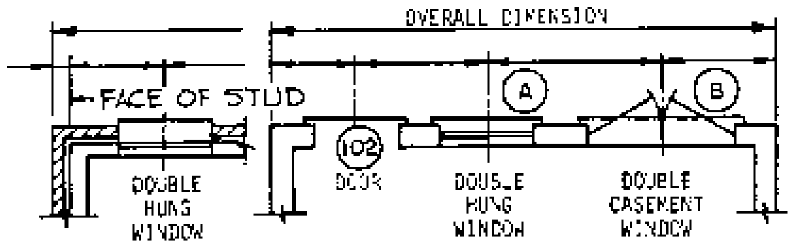


INTERIOR PARTITIONS

DIMENSIONING AND INDICATIONS OF WINDOWS AND DOORS:



EXTERIOR MASONRY WALLS

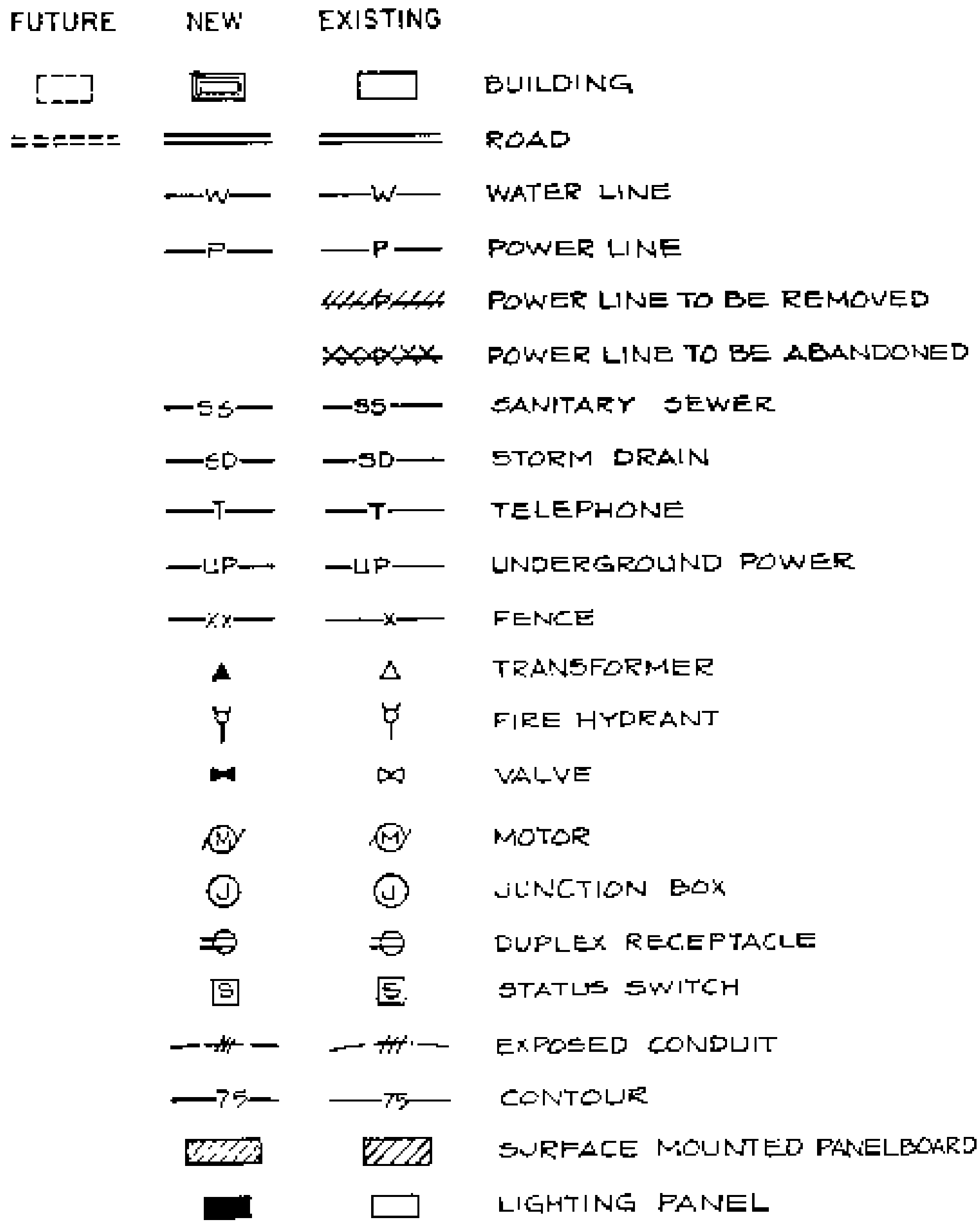


B R I C K   V E N E E R   EXTERIOR FRAME WALLS

12-16

CONVENTIONS
LEGEND FORMAT

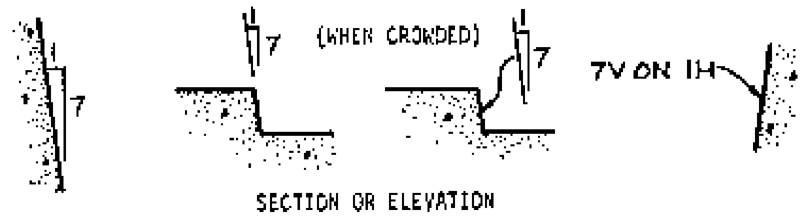
LEGEND



12-17

CONVENTIONS
MISCELLANEOUS

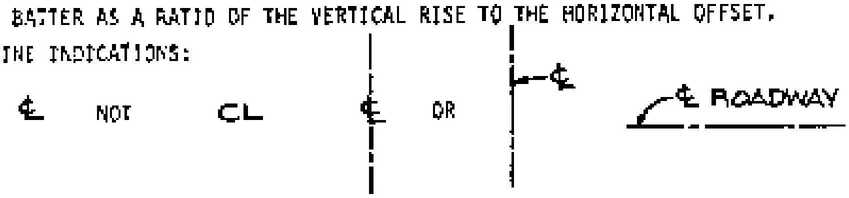
BATTER: APPLICABLE FOR CONCRETE WORK OR ROCK EXCAVATION



SECTION OR ELEVATION

GIVE BATTER AS A RATIO OF THE VERTICAL RISE TO THE HORIZONTAL OFFSET.

CENTER LINE INDICATIONS:



PREFERRED

FRACTIONS AND WHOLE NUMBERS:

$4\frac{1}{4}$ OR 4¼ NOT 4 1/4 $6'-2\frac{1}{2}''$

CENTER INCH AND FOOT MARKS ON CAP LINE EXCEPT FOR FRACTIONS

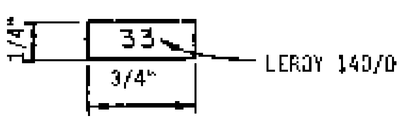
DECIMAL FRACTIONS SHALL ALWAYS HAVE A CIPHER BEFORE THE DECIMAL POINT:

0.2 0.95 0.5279 0.037 0.0005

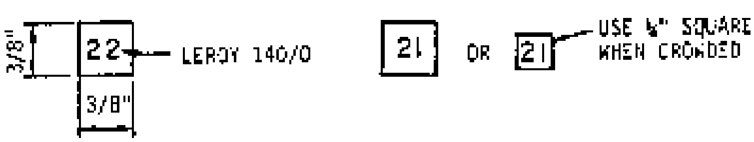
COMMAS SHALL BE USED IN NUMBERS CONTAINING FOUR OR MORE DIGITS, EXCEPT DECIMAL FRACTIONS, SERIAL NUMBER, ETC.

6,250 3,268,971 CATALOG NO. 7321 0.1253

PAYMENT ITEM NUMBERS:

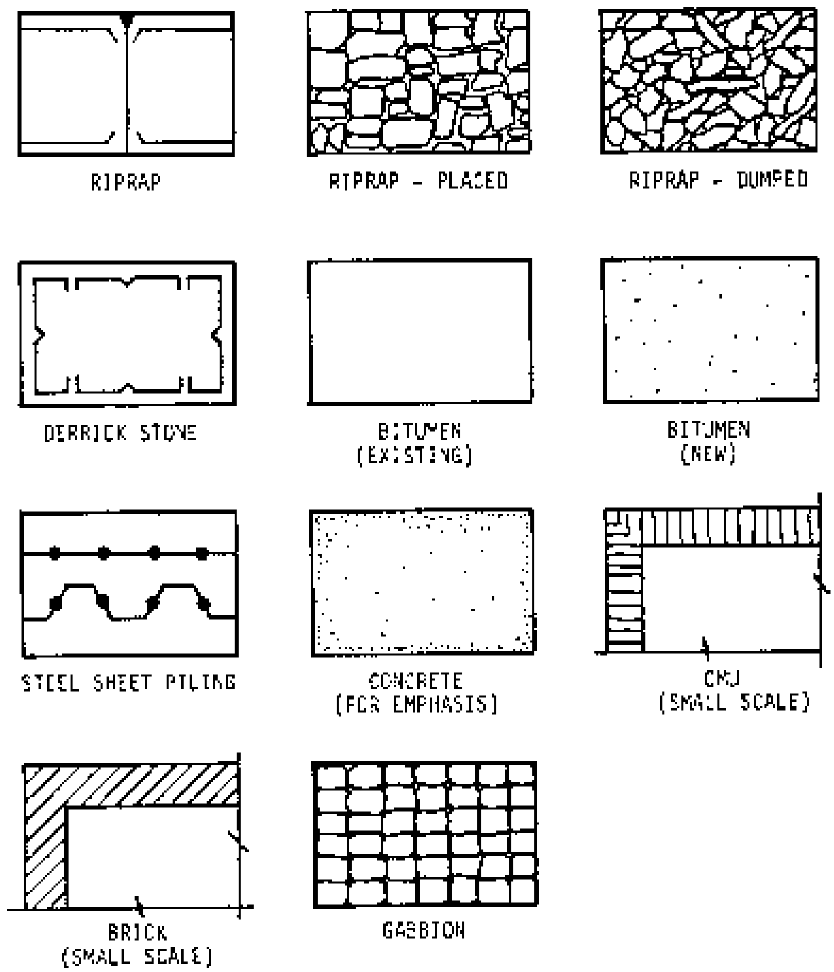


UNIT NUMBERS:



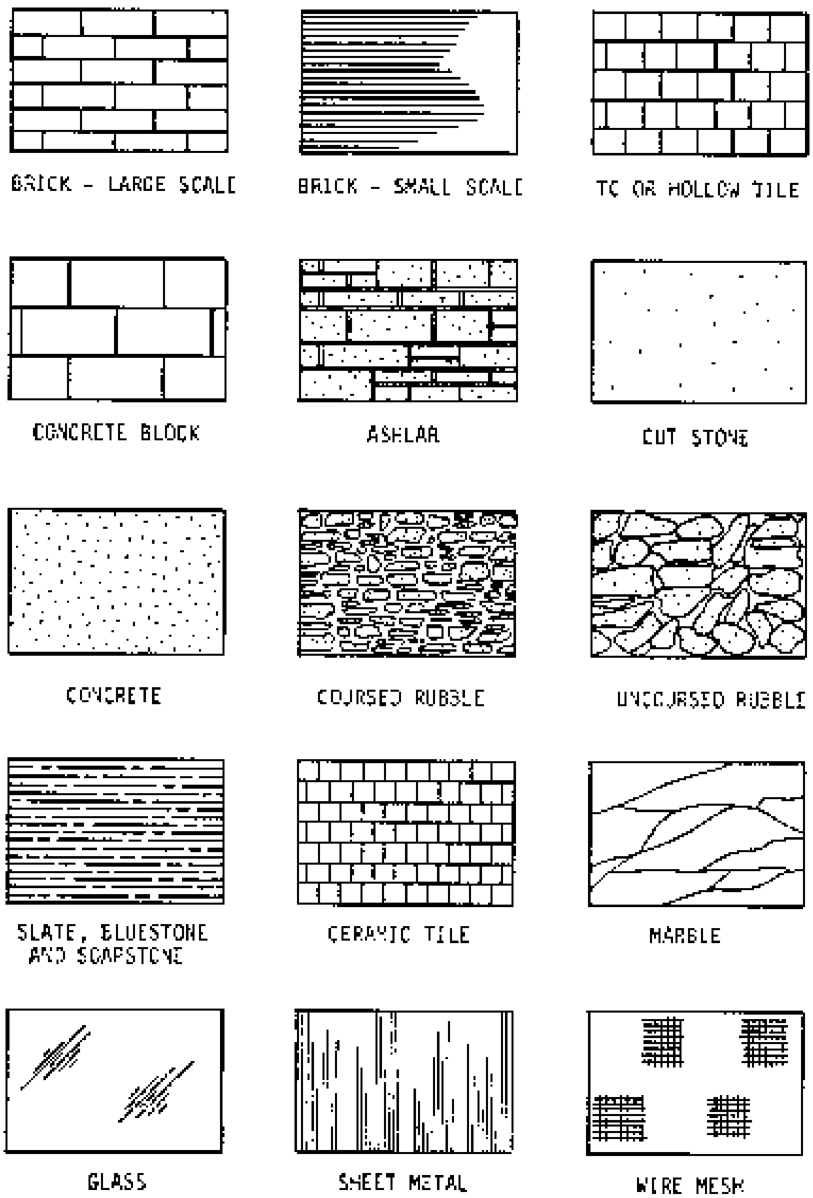
ENGINEERING SYMBOLS
MATERIAL

PLAN



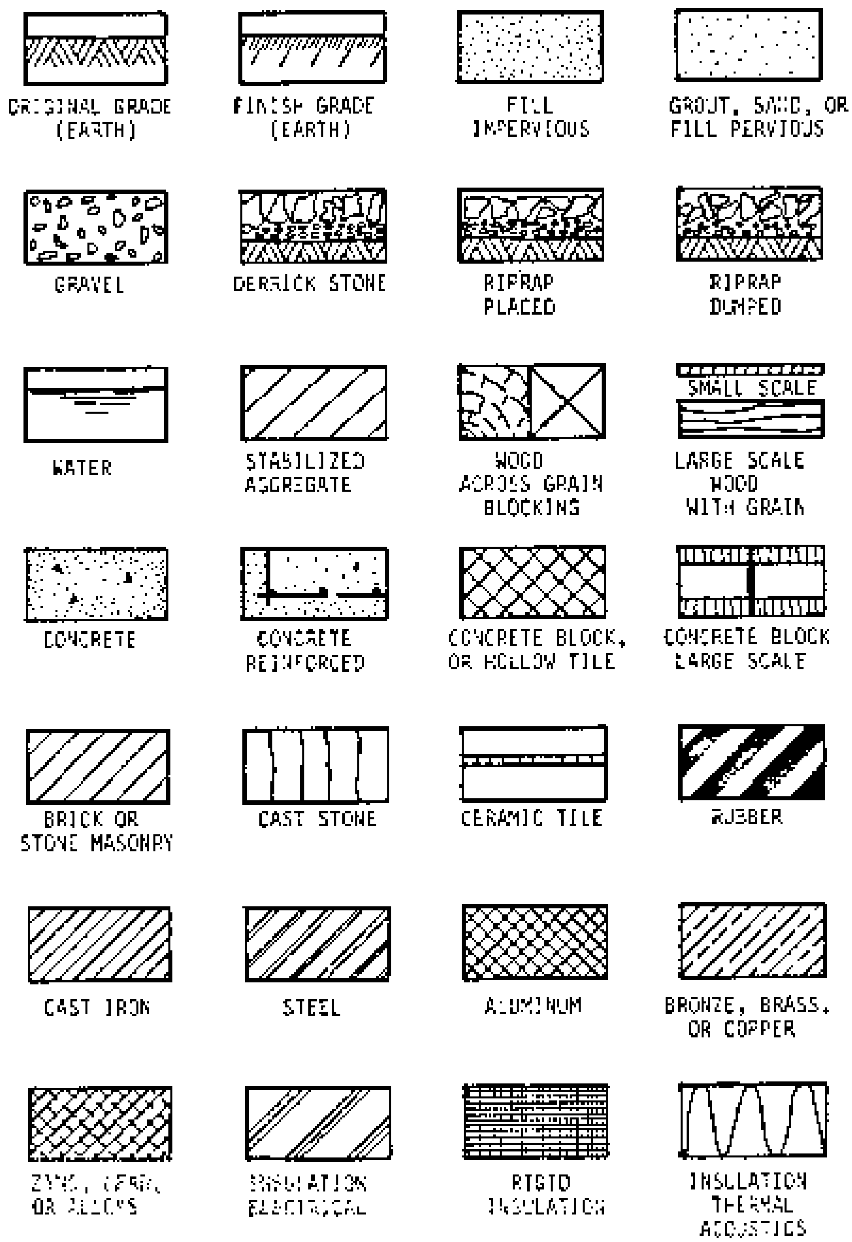
ENGINEERING SYMBOLS
MATERIAL

ELEVATION



ENGINEERING SYMBOLS
MATERIAL

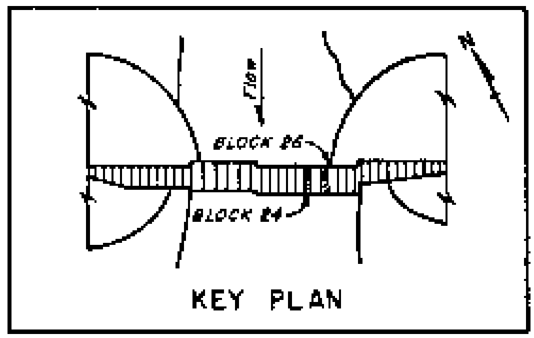
SECTION



KEY PLANS AND MATCH LINE

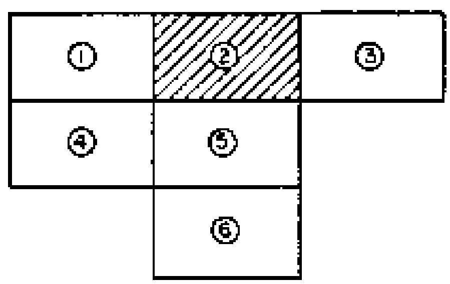
KEY PLAN:

FOR DAMS, STRUCTURES, BUILDINGS, ETC.



SHEET INDEX:

FOR TOPOGRAPHIC MAPS, SURVEYS, RIVERS, LAKES, ETC.



NOTE:

KEY TO SETS OF DRAWINGS MAY APPEAR ON THE FIRST SHEET OR EACH SHEET, WHICHEVER SERVES THE BEST PURPOSE. LOCATE ABOVE TITLE BLOCK, SEE "SHEET LAYOUT FORMAT".

MATCH LINE:

PLATE P-2
OR SHEET 2

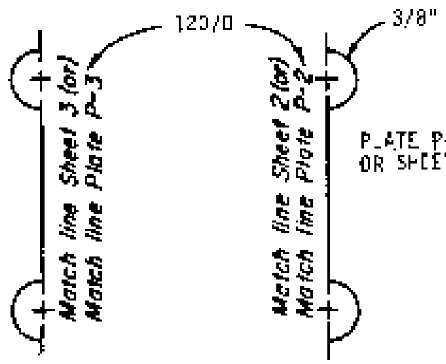
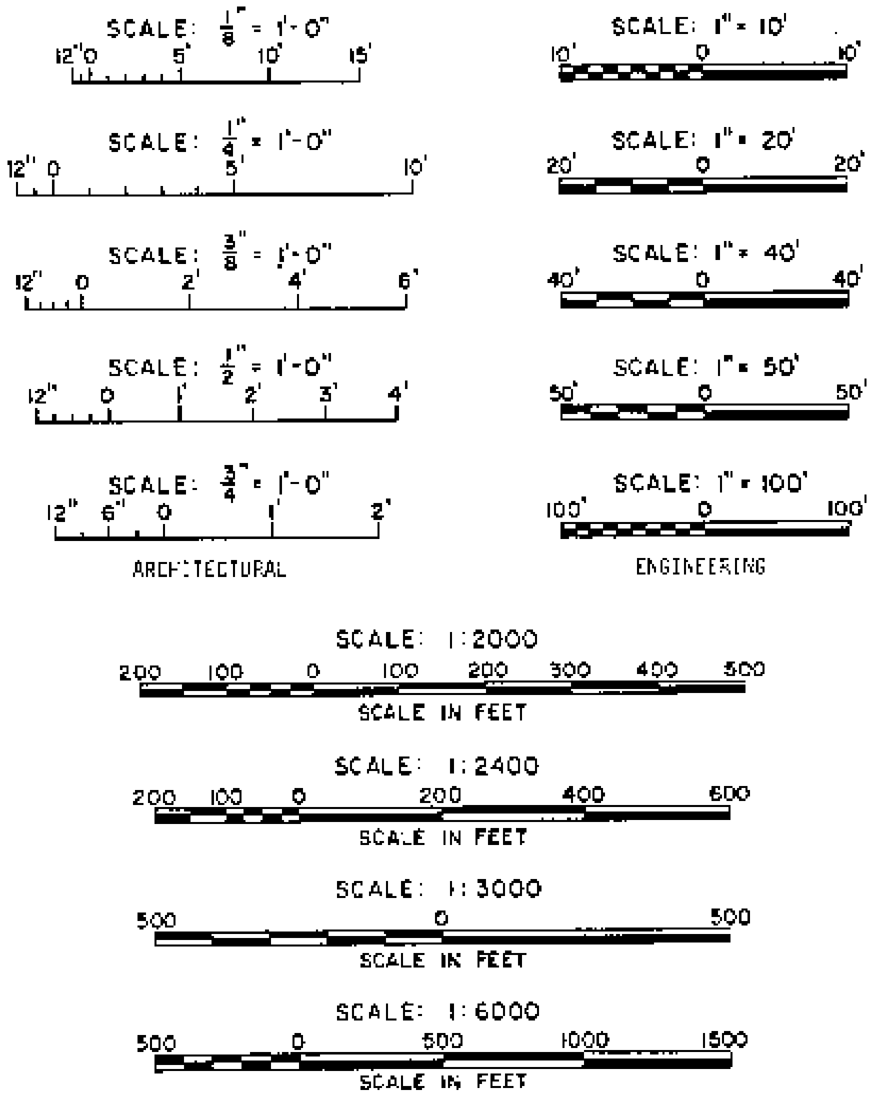


PLATE P-3
OR SHEET 3

12-22

GRAPHIC SCALES

EXAMPLE - FREQUENTLY USED SCALES:



NOTE:

SHOW A GRAPHIC SCALE FOR EACH DIFFERENT SCALE USED ON A DRAWING. CENTER SCALE DIRECTLY UNDER THE TITLE OR, AS AN ALTERNATIVE, IN A GROUP NEAR THE TITLE BLOCK.

NORTH ARROWS

ORIENTATION:

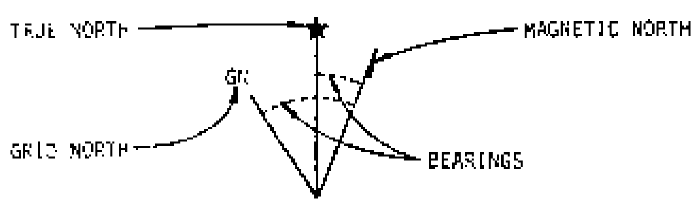
ORIENT ALL PLAN VIEWS SO THAT NORTH WILL BE TOWARD THE TOP OF THE SHEET WHEN PRACTICAL OR TOWARD THE LEFT OF THE SHEET IF TOP ORIENTATION IS IMPRACTICAL.

PLACE THE NORTH ARROW AT THE TOP AND TO THE RIGHT SIDE OF PLAN VIEW IF POSSIBLE.

NORTH ARROW FOR VICINITY MAPS AND DRAWING SIZES SMALLER THAN 17" x 22"

NORTH ARROW FOR DRAWING SIZES 17" x 22" OR LARGER

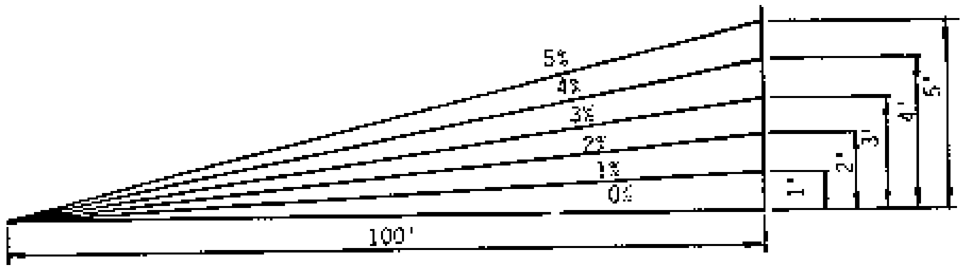
DECLINATION OF NORTH AS REQUIRED FOR SPECIAL USE:



12-24

SLOPE EXPRESSIONS

PERCENTAGE:



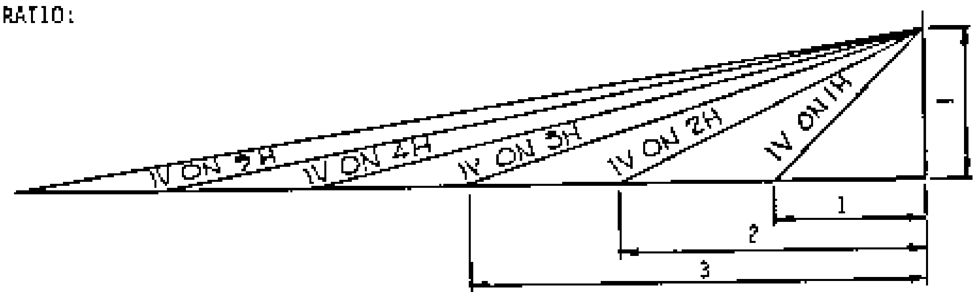
1% SLOPE RISES 1' IN DISTANCE OF 100'

2% SLOPE RISES 2' IN DISTANCE OF 100'

2.5% SLOPE RISES 2½' IN DISTANCE OF 100'

2.75% SLOPE RISES 2 3/4' IN DISTANCE OF 100'

RATIO:

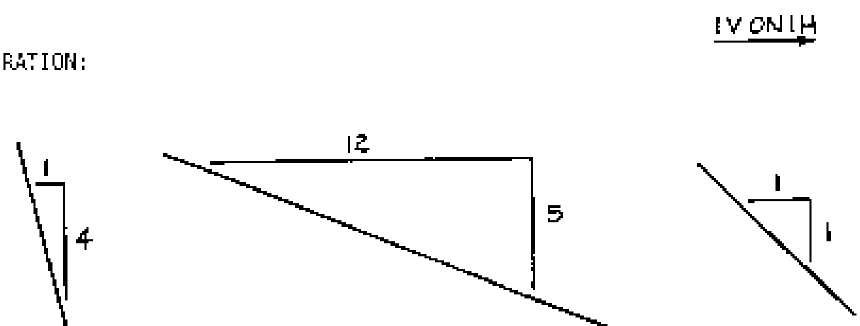


1V ON 1H SLOPE RISES 1' IN DISTANCE OF 1'

1V ON 2H SLOPE RISES 1' IN DISTANCE OF 2'

1V ON 3H SLOPE RISES 1' IN DISTANCE OF 3'

ILLUSTRATION:



12-25

MECHANICAL SYMBOLS
PIPING

AIR CONDITIONING AND REFRIGERATION:

CHILLED WATER SUPPLY	CHS
CHILLED WATER RETURN	CHR
CONDENSER WATER SUPPLY	CS
CONDENSER WATER RETURN	CR
DRAIN	D
DUAL TEMPERATURE RETURN	DTR
DUAL TEMPERATURE SUPPLY	DTS
HUMIDIFICATION LINE	H
REFRIGERANT DISCHARGE	RD
REFRIGERANT LIQUID	RL
REFRIGERANT SUCTION	RS

HEAT AND POWER:

BOILER BLOW OFF	BBO
CONDENSATE OR VACUUM PUMP DISCHARGE	
FEEDWATER PUMP DISCHARGE	FW
FUEL OIL FLOW	FOF
FUEL OIL RETURN	FOR
FUEL OIL TRANSFER	FOT
FUEL OIL VENT	FOV
HIGH PRESSURE STEAM	
HIGH PRESSURE CONDENSATE RETURN	
HIGH TEMPERATURE WATER SUPPLY	HTWS
HIGH TEMPERATURE WATER RETURN	HTWR
HOT WATER HEATING SUPPLY	HWS
HOT WATER HEATING RETURN	HWR

12-26

MECHANICAL SYMBOLS
PIPING

HEAT AND POWER CONTINUED:

LOW PRESSURE STEAM	
LOW PRESSURE RETURN	
LUBRICATION OIL	LO
MEDIUM PRESSURE STEAM	
MEDIUM PRESSURE CONDENSATE RETURN	
PIPE ANCHOR	P.A.

PLUMBING:

ACETYLENE	AC
ACID RESISTANT WASTE LINE	AR
CLEANOUT ABOVE GRADE	C.O.
CLEANOUT FLOOR	F.C.O.
CLEANOUT GRADE	G.C.O.
CLEANOUT WALL	W.C.O.
COLD WATER	
COMPRESSED AIR	A
DRAIN FLOOR	F.D.
DRAIN OPEN SIGHT	O.S.D.
FAUCET	
FOAM	FOAM
GAS	G
GASOLINE	GASO
GAS SHUT-OFF VALVE IN CAST IRON VALVE BOX	
HOSE, LAWN FAUCET OR WALL HYDRANT AND DESIGNATION	L.F.
HOSE BIBB	HB
HOT WATER	

12-27

MECHANICAL SYMBOLS

PIPING

HOT WATER RETURN RECIRCULATING	
HYDROGEN	HY
NITROUS OXIDE	N_2O
OXYGEN	OX
PNEUMATIC	PN
PNEUMATIC TUBE RUN	
ROOF DRAIN	RD
SALT WATER	SW
STORM DRAIN	SD
SANITARY SEWER	SS
TEMPERED WATER	T
VACCUM	V
VENT	
VENT TIE BACK	VTB
VENT THROUGH ROOF	VTR
WASTE LINE (ABOVE AND BELOW GRADE)	

SPRINKLERS:

BRANCH AND HEAD (UPRIGHT)	
BRANCH AND HEAD (PENDANT)	
DRAIN	S S
MAIN SUPPLY	S
RISER AND SIZE	4"
FOAM SPRINKLER PIPE	FS
FIRE MONITER PIPE	FM
HALON PIPE	H

12-28

MECHANICAL SYMBOLS
FITTINGS AND VALVES

CONNECTION TYPES:

FLANGED OR | SCREWED OR | BELL & SPIGOT OR | WELDED OR | SOLDERED OR

PIPE FITTINGS:

BASE ELBOW

CROSS

ELBOW - 45 DEGREES

ELBOW - 90 DEGREES

ELBOW - LONG RADIUS L.R.

ELBOW - TURNED DOWN

ELBOW - TURNED UP

EXPANSION JOINT - BELLOWS

EXPANSION JOINT - SLIDING

FLEXIBLE CONNECTIONS
VIBRATION ELIMINATORS

LATERAL

REDUCER - CONCENTRIC

REDUCER - ECCENTRIC

REDUCING ELBOW

REDUCING FLANGE

SLEEVE

TEE

TEE OUTLET - DOWN

TEE OUT LET - UP

UNION - FLANGED

UNION SCREWED

CONNECTION TYPES:

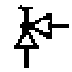
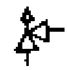
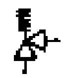
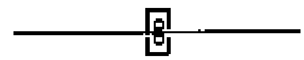
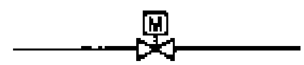
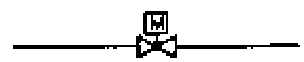
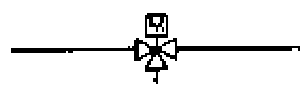
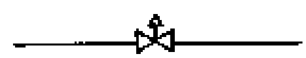
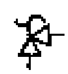
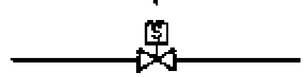
FLANGED | SCREWED | BELL & SPIGOT | WELDED | SOLDERED

NOTE:

SCREWED END REPRESENTATION MAY BE USED FOR ALL TYPES OF CONNECTIONS PROVIDED THE TYPE OF CONNECTION IS COVERED BY DRAWING LEGEND, NOTE OR SPECIFICATIONS

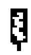
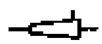
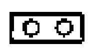
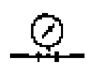
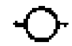
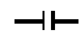
12-29

MECHANICAL SYMBOLS
VALVES

ANGLE GLOBE VALVE	
ANGLE NEEDLE VALVE	
BOILER SAFETY PRESSURE RELIEF VALVE	
CHECK VALVE	
CONTROL VALVE	
DUPLEX STRAINER	
GATE VALVE	
GLOBE VALVE	
HOSE GATE VALVE	
HOSE GLOBE VALVE	
MOTOR OPERATED GATE VALVE	
MOTOR OPERATED GLOBE VALVE	
MOTOR OPERATED 3-WAY VALVE	
NEEDLE VALVE	
PLUG VALVE OR BALANCING COCK	
PRESSURE REDUCING VALVE	
PRESSURE RELIEF VALVE	
SOLENOID OPERATED VALVE	
STRAINER	

12-10

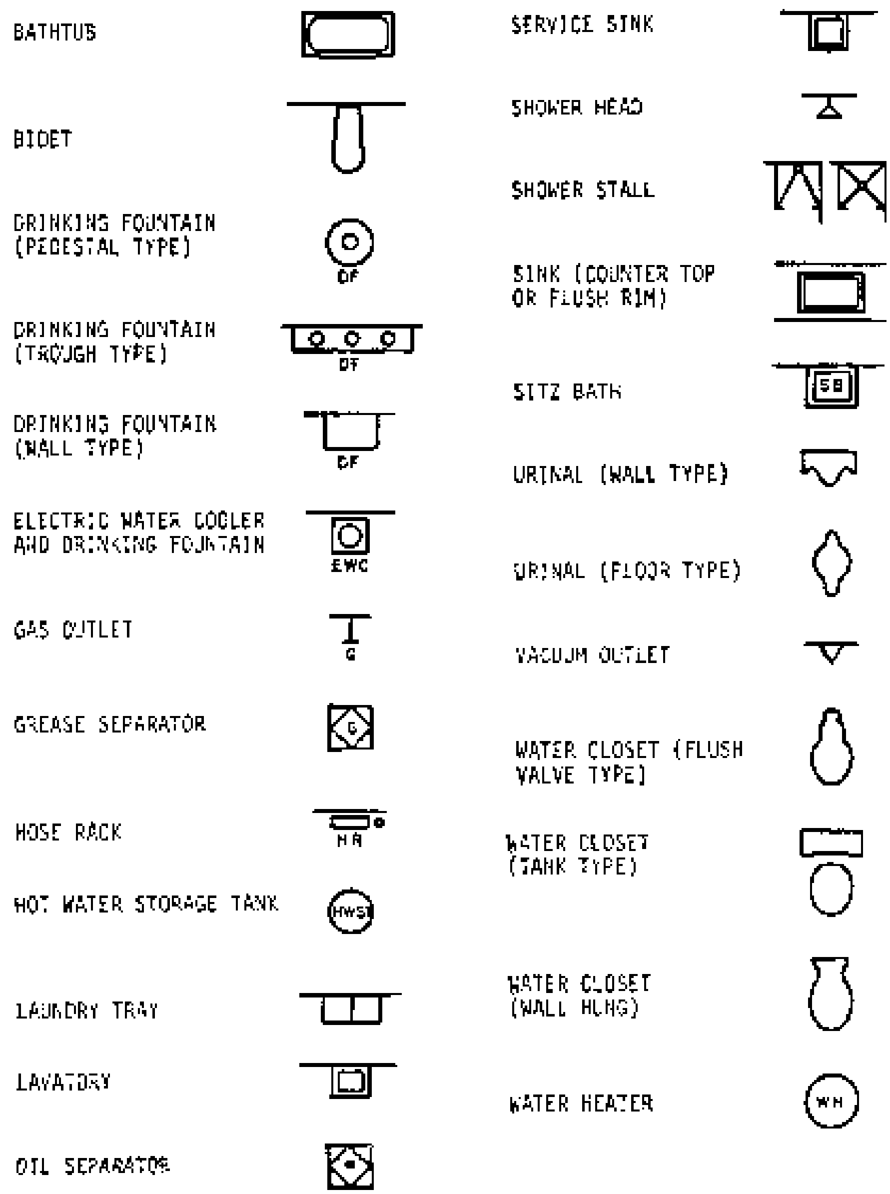
MECHANICAL SYMBOLS
GAGES, INSTRUMENTS AND MISCELLANEOUS

AIRCHAMBER	
AUTOMATIC AIR VENT	
COMPRESSED AIR OUTLET	
DIRECT READING THERMOMETER-BARE BULB TYPE	
DIRECT READING THERMOMETER-SEPARABLE SOCKET TYPE	
EDUCTOR	
FILTER-OIL DUPLEX	
GAGE GLASS	
HUMIDISTAT	
PRESSURE GAGE	
METER	
ORIFICE	
OXYGEN OUTLET	
NITROUS OXIDE OUTLET	
THERMOSTAT (REMOTE BULB OR SELF CONTAINED)	
VACUUM GAGE	
VACUUM-PRESSURE GAGE	
VACUUM OUTLET	

MECHANICAL SYMBOLS

ARCHITECTURAL REPRESENTATIONS

PLUMBING FIXTURES:



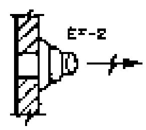
MECHANICAL SYMBOLS
HEATING, VENTILATING AND AIR CONDITIONING

FANS, HEATERS AND VENTILATORS:

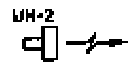
CENTRIFUGAL ROOF EXHAUST FAN AND DESIGNATION

GRAVITY ROOF VENTILATOR

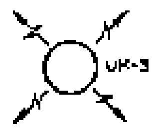
CENTRIFUGAL WALL EXHAUST FAN AND DESIGNATION



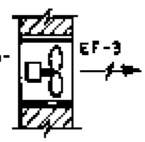
UNIT HEATER AND DESIGNATION



UNIT HEATER-VERTICAL AND DESIGNATION



PROPELLER TYPE WALL MOUNTED FAN AND DESIGNATION



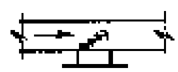
UNIT VENTILATOR

CONVECTOR AND DESIGNATION

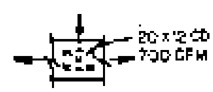
RADIATOR AND DESIGNATION

DUCTWORK:

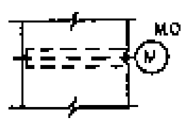
AIR DEFLECTOR



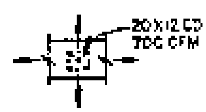
CEILING DIFFUSER - RECTANGULAR OR SQUARE, 3-WAY THROW



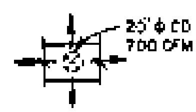
AUTOMATIC DAMPERS - MOTOR OPERATED



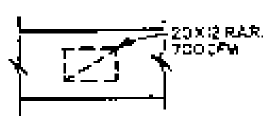
CEILING DIFFUSER - RECTANGULAR OR SQUARE, 4-WAY THROW



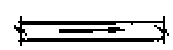
CEILING DIFFUSER - ROUND



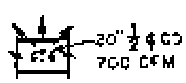
CEILING RETURN AIR REGISTER/GRILLE



DIRECTION OF FLOW

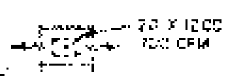


CEILING DIFFUSER - HALF-ROUND

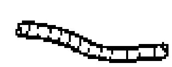


RECTANGULAR DUCT - FIRST FIGURE WIDTH, SECOND DEPTH

CEILING DIFFUSER - RECTANGULAR OR SQUARE, 2-WAY THROW

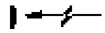


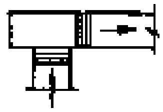
FLEXIBLE DUCT

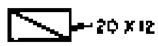


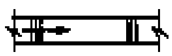
MECHANICAL SYMBOLS
HEATING, VENTILATING AND AIR CONDITIONING

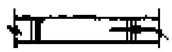
DUCTWORK: (CONTINUED)

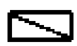
EXHAUST INLET 

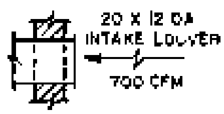
FLEXIBLE CONNECTIONS 

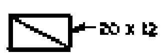
OUTSIDE AIR DUCT SECTION 

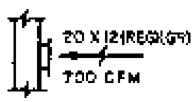
INCLINED DROP IN RESPECT TO AIR FLOW 

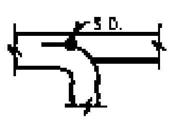
INCLINED RISE IN RESPECT TO AIR FLOW 

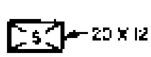
OTHER DUCTS SECTION 

OUTSIDE AIR IN-TAKE LOUVER 

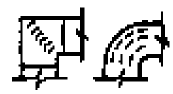
RETURN OR EXHAUST DUCT SECTION 

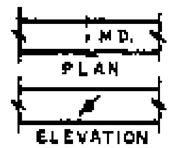
REGISTER OR GRILLE AND CFM CAPACITY - SIDE WALL 

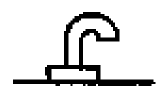
SPLITTER DAMPER 

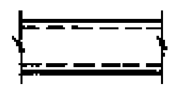
SUPPLY DUCT SECTION 

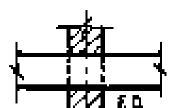
SUPPLY OUTLET 

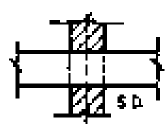
TURNING VANES 

VOLUME CONTROL DAMPER (MANUAL) 

GOOSENECK ON ROOF 

ACCOUSTICALLY LINED DUCT 

FIRE DAMPER IN DUCT PENETRATION OF WALL 

MOTOR OPERATED SMOKE DAMPER IN DUCT PENETRATION OF WALL 

ELECTRICAL SYMBOLS
EXTERIOR

AERIAL:

ALSO REFER TO THE TOPOGRAPHY - EXTERIOR UTILITIES PORTION OF THIS VOLUME

	EXISTING	NEW
POLE - LENGTH AND CLASS INDICATED	35-5	35-5
POLE WITH DOWN GUY AND ANCHOR - LENGTH AND CLASS OF POLE AND STRENGTH OF GUY IN POUNDS AS INDICATED.	35-5-4M	35-5-4M
TRANSFORMER INSTALLATION - DESIGNATION 1-25-1 INDICATES QUANTITY, KVA AND TRANSFORMER PHASES, RESPECTIVELY; I.E., ONE 25 KVA SINGLE PHASE. SYMBOL IMPLIES LIGHTNING ARRESTERS AND FUSED CUTOUTS. ALSO, AS SHOWN ON TYPICAL OR SPECIAL DETAILS ON DRAWING. PHASE CONNECTION AS INDICATED.	1-25-1	1-25-1
POLE WITH STREET LIGHT - LENGTH AND CLASS OF POLE TYPE AND SIZE OF LUMINAIRE.*	35-5 SF2500 110	35-5 SF2500 110

STREET LIGHTING REGULATOR-RATING IN KW AS INDICATED	15
SECTIONALIZING SWITCH MOUNTED ON CROSSARM - NORMALLY OPEN	
SECTIONALIZING SWITCH MOUNTED ON CROSSARM - NORMALLY CLOSED	
AUTOMATIC CIRCUIT RECLOSER	R
AUTOMATIC LINE SECTIONALIZER	S
LIGHTNING ARRESTER IN EACH PHASE WIRE	LA
PRIMARY LINE - NUMBER, SIZE, AND VOLTAGE OF WIRES AS INDICATED	3#2-15KV
STREET LIGHTING SERIES - WIRE, NUMBER AND SIZE AS INDICATED	2#6 SLS
STREET LIGHTING MULTIPLE - WIRE, NUMBER AND SIZE AS INDICATED	2#6 SLM
THREE PHASE SECONDARY LINE - NUMBER AND SIZE OF WIRES AS INDICATED	3#2
SINGLE PHASE SECONDARY LINE - NUMBER AND SIZE OF WIRES AS INDICATED	3#2

STREET LIGHT DESIGNATIONS:

COLOR CORRECTED MERCURY FOLLOWED BY WATTAGE	C
SERIES	S
MULTIPLE	P
PHOTO-ELECTRIC CONTROL	PH
FILAMENT LAMP - FOLLOWED BY LUMEN SIZE OR WATTAGE	F
MERCURY VAPOR LAMP - FOLLOWED BY WATTAGE	M
IES DISTRIBUTION TYPE	II, III, IV, V
ENCLOSED	E
OPEN	O

NOTE:

NUMBER, SIZES, AND VOLTAGES OF CONDUCTORS MAY BE IDENTIFIED BY NOTATION OR SCHEDULE.

ELECTRICAL SYMBOLS
EXTERIOR

UNDERGROUND:	EXISTING	NEW
MANHOLE-NUMBER AND TYPE AS INDICATED	M	M2O-T
HANDHOLE	H	H
TRANSFORMER MANHOLE OR VAULT	TM	TM
TRANSFORMER MOUNTED ON CONCRETE PAD (DESCRIBE)		
UNDERGROUND DIRECT BURIAL CABLE. INDICATE TYPE, SIZE, NUMBER OF CONDUCTORS AND VOLTAGE. SEE NOTES BELOW.	4#2/0-15KV	4#2/0-15KV
UNDERGROUND DUCT LINE. INDICATE TYPE, SIZE AND NUMBER OF DUCTS AND CONDUCTORS BY NOTATION OR SCHEDULE. SEE NOTES BELOW.	4#2/0-15KV 4"-4W	4 2/0-15KV 4"-4W
STREET LIGHTING STANDARD FED FROM UNDERGROUND		

NOTES:

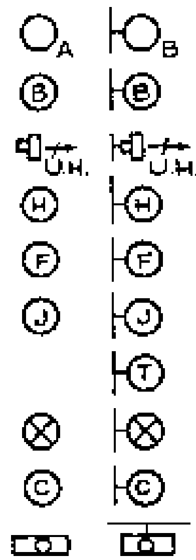
1. SINGLE CONDUCTOR CABLES SHALL BE INDICATED AS FOLLOWS: 4#2/0-15KV; 3#2-5KV AND 1#6-600V; OR 3-1/C #500 MCM-15KV.
2. THREE CONDUCTOR CABLES SHALL BE INDICATED AS FOLLOWS: 3/C #4/0-15KV; 3/C 500 MCM.
3. DUCTS SHALL BE INDICATED AS FOLLOWS: 6"-4W, 4"-8W, 5"-4W, WITH 4W INDICATING FOUR DUCTS, 8W INDICATING 8 DUCTS, ETC.
4. SPECIFY GROUNDED OR UNGROUNDED AND SHIELDING OF CONDUCTORS BY NOTE OR SPECIFICATION.
5. SYMBOLS ARE FOR ILLUSTRATIVE PURPOSES ONLY. VARY TO SUIT SCALE OF DRAWING.

12-36

ELECTRICAL SYMBOLS
INTERIOR

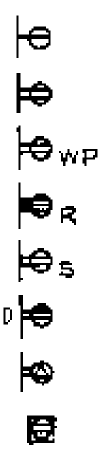
GENERAL OUTLETS:

CEILING WALL



- LIGHTING OUTLET SUBSCRIPT DESIGNATES FIXTURE TYPE
- BLANKED OUTLET
- UNIT HEATER
- ELECTRIC HEATER
- EXHAUST FAN
- JUNCTION BOX
- THERMOSTAT
- EXIT LIGHT OUTLET
- CLOCK OUTLET
- FLUORESCENT FIXTURE OUTLET - DESIGNATE TYPE

CONVENIENCE OUTLETS:



- SINGLE RECEPTACLE
- DUPLEX RECEPTACLE
- WEATHERPROOF RECEPTACLE
- RANGE OUTLET
- SWITCH AND RECEPTACLE
- DUPLEX RECEPTACLE-SPLIT WIRED
- SPECIAL PURPOSE OUTLET - (DESIGNATE IN SPEC)
- FLOOR OUTLET - DUPLEX RECEPTACLE

SWITCH OUTLETS:

SINGLE POLE SWITCH	S
DOUBLE POLE SWITCH	S_2
THREE WAY SWITCH	S_3
FOUR WAY SWITCH	S_4
DOOR SWITCH	S_D
SWITCH FOR LOW VOLTAGE SYSTEM	S_L
KEY OPERATED SWITCH	S_K
SWITCH OPERATED PILOT LAMP	S_P
MOMENTARY CONTACT SWITCH	S_{MC}
REMOTE CONTROL SWITCH	S_{RC}
WEATHERPROOF SWITCH	S_{WP}

FLOODLIGHTS; INTERIOR OR EXTERIOR

CEILING WALL OR POLE

NOTE: ARROW INDICATES DIRECTION OF BEAM.

NOTE:

SYMBOLS NOT SHOWN WILL CONFORM TO "AMERICAN NATIONAL STANDARDS INSTITUTE".

12-37

ELECTRICAL SYMBOLS
INTERIOR CONTINUED

PANELS, CIRCUITS, AND MISCELLANEOUS:

LIGHTING PANEL

POWER PANEL

COMBINATION PANEL

BRANCH CIRCUIT; CONCEALED IN CEILING OR WALL

BRANCH CIRCUIT; CONCEALED IN OR BELOW FLOOR

BRANCH CIRCUIT; EXPOSED

HOME RUN TO PANEL BOARD INDICATE NUMBER OF CIRCUITS BY NUMBER OF ARROWS. ANY CIRCUIT WITHOUT FURTHER DESIGNATION INDICATES A TWO-WIRE CIRCUIT. FOR A GREATER NUMBER OF WIRES INDICATE AS FOLLOWS:

(3 WIRES); (4 WIRES), ETC.

FEEDERS

AUXILIARY SYSTEM CIRCUITS

UNDERFLOOR DUCT AND JUNCTION BOX-TRIPLE, DOUBLE OR SINGLE DUCT SYSTEM IS DESIGNATED BY NUMBER OF PARALLEL LINES

GENERATOR-SUBSCRIPT DESIGNATES KW RATING

MOTOR-SUBSCRIPT DESIGNATES H.P. SIZE

SERVICE SWITCH OR BREAKER

CONTROLLER

DISCONNECT SWITCH

AUXILIARY SYSTEMS:

PUSH BUTTON

BUZZER

BELL

ANNUNCIATOR

TELEPHONE

INTERCOMMUNICATION TELEPHONE

TELEPHONE SWITCHBOARD

BELL RINGING TRANSFORMER

TELEVISION

FIRE ALARM BELL

FIRE ALARM STATION

CITY FIRE ALARM STATION

FIRE ALARM CENTRAL STATION

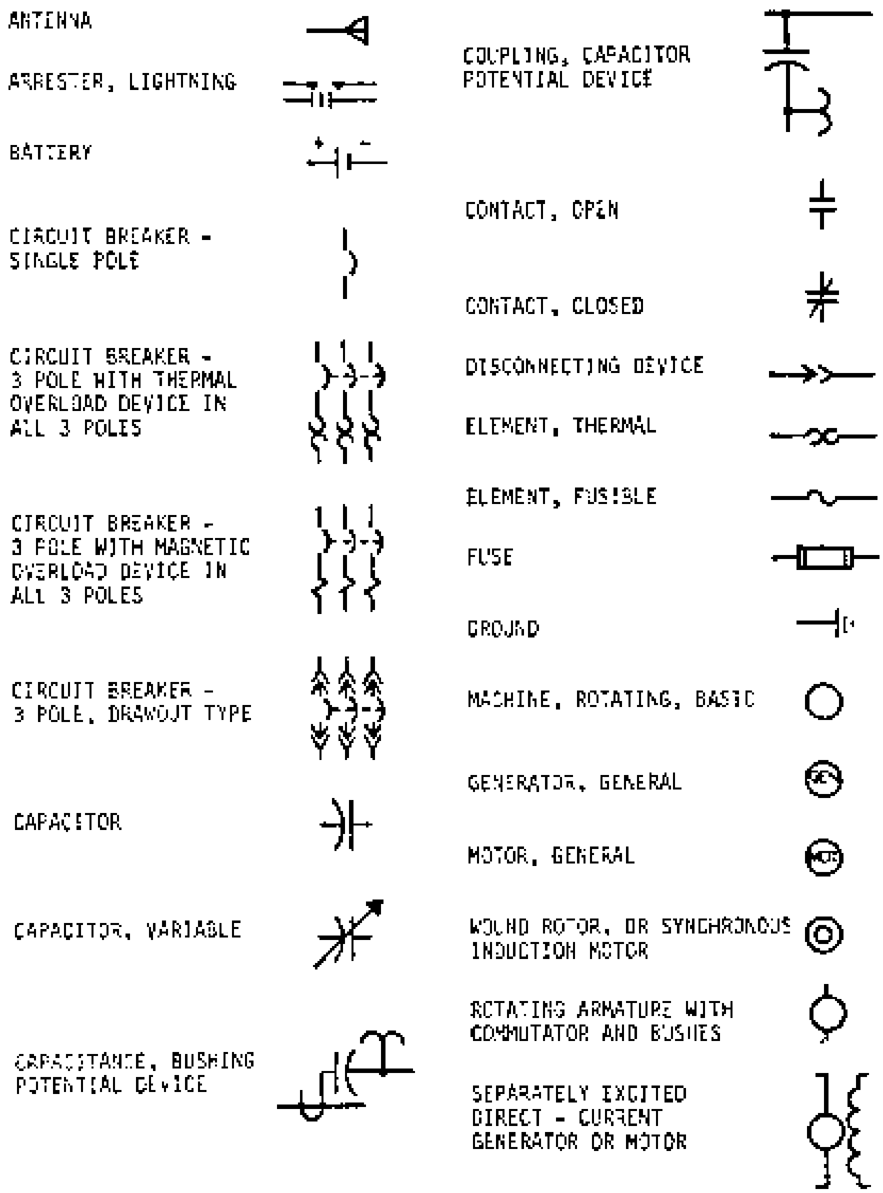
AUTOMATIC FIRE ALARM DEVICE

HORN

NOTE:
SYMBOLS NOT SHOWN WILL CONFORM TO "AMERICAN NATIONAL STANDARDS INSTITUTE".

12-38

ELECTRICAL SYMBOLS
SCHEMATIC AND DIAGRAMMATIC



NOTE:

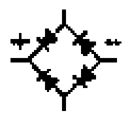
FOR SYMBOLS NOT SHOWN SEE "AMERICAN NATIONAL STANDARDS INSTITUTE".

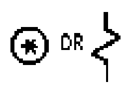
12-39

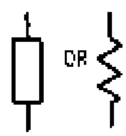
ELECTRICAL SYMBOLS
SCHEMATIC AND DIAGRAMMATIC

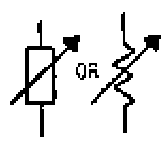
METER OR INSTRUMENT
* LETTER DENOTES TYPE 

DIODE 

RECTIFIER-FULL-WAVE BRIDGE 

RELAY COIL
* IDENTIFYING LETTER OR NUMBER 

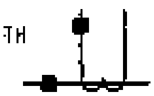
RESISTOR 

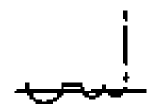
RESISTOR-VARIABLE 

SWITCH-SINGLE THROW 

SWITCH WITH HORN GAP 

TRANSFORMER-GENERAL 

TRANSFORMER-CURRENT WITH POLARITY MARKING 

TRANSFORMER-CURRENT, BUSHING TYPE 

TRANSFORMER-POTENTIAL 

NOTE:
FOR SYMBOLS NOT SHOWN SEE "AMERICAN NATIONAL STANDARDS INSTITUTE".

TOPOGRAPHIC SYMBOLS

SURVEY DATA

CONTROL POINTS:

BENCH MARK - PERMANENT

BENCH MARK - TEMPORARY

IRON ROD - TEMPORARY

CONCRETE MONUMENT - PERMANENT

BASE LINE - STATION NUMBERS

TRAVERSE LINE

AZIMUTH DISTANCE AND HUB NUMBER

COORDINATE IDENTIFICATION

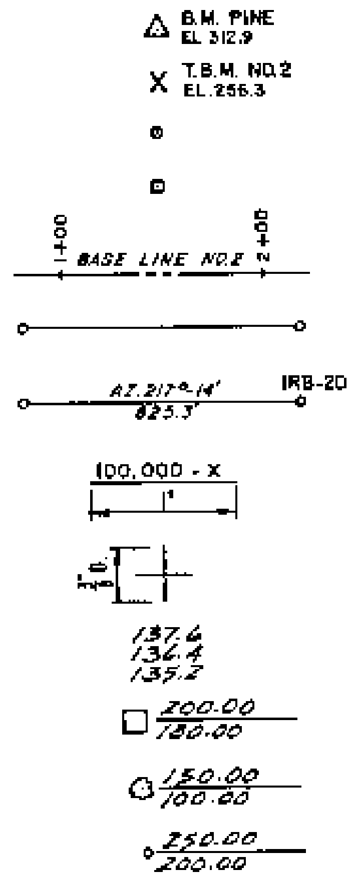
COORDINATE INTERSECTION

SPOT ELEVATIONS

BUILDING WITH TOP AND GROUND ELEVATIONS

INDIVIDUAL TREE WITH TOP AND GROUND ELEVATIONS

POWER POLE WITH TOP AND GROUND ELEVATIONS



TOPOGRAPHY

CONTOURS

TYPES:

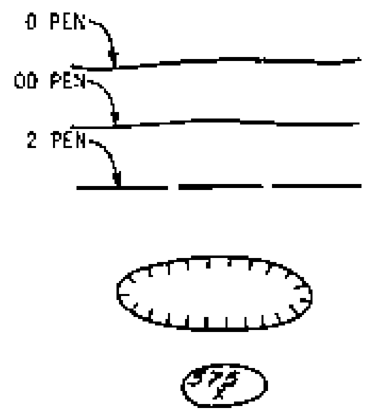
INDEX

INTERMEDIATE

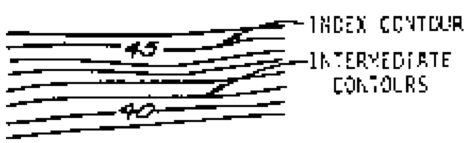
FINISHED GRADE

DEPRESSION

HILLTOP

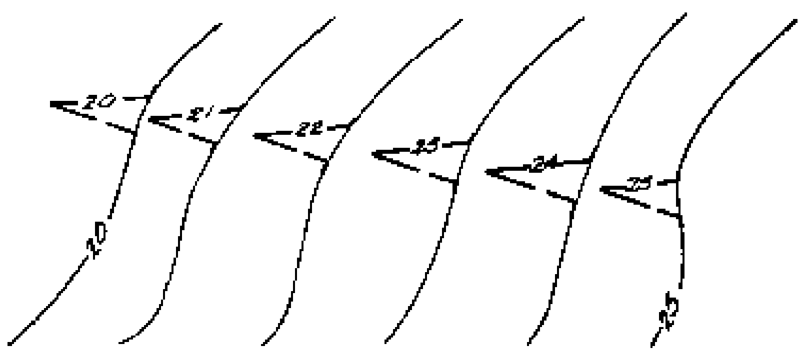


EXAMPLE:



NOTE:
LABEL EACH INDEX CONTOUR WITH SLANT LETTERING

EXAMPLE - EXISTING TOPO WITH FINISHED GRADE CONTOURS:



TOPOGRAPHY

BOUNDARIES AND DRAINAGE

BOUNDARIES:

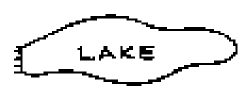
CITY (INC.), TOWN, VILLAGE	00 PEN	
COUNTY LINE	1 PEN	
CONSTRUCTION LIMITS	4 PEN	
DRAINAGE BASIN BOUNDARY	4 PEN	
EASEMENT LINE	00 PEN	
RIGHT-OF-WAY LINE	00 PEN	R/W
RESERVATION LINE	2 PEN	
STATE LINE	3 PEN	

DRAINAGE:

CANAL

DITCH

LAKE OR POND WITH DAM



STREAMS:

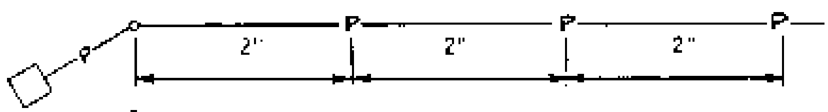
PERENNIAL — CEDAR CREEK

INTERMITTENT

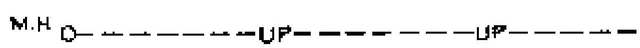
TOPOGRAPHY MAPPING
EXTERIOR UTILITIES

	00 PEN
FUEL LINE	——— F ———
GAS LINE	——— G ———
INDUSTRIAL WASTE LINE	——— IW ———
POWER LINE - AERIAL	——— P ———
POWER LINE - UNDERGROUND	- - - - UP - - - -
SANITARY SEWER LINE	——— SS ———
STEAM LINE	——— S ———
STORM DRAINAGE LINE	——— SD ———
TELEPHONE LINE - AERIAL	——— T ———
TELEPHONE LINE - UNDERGROUND	- - - - UT - - - -
TELEPHONE AND POWER - AERIAL	——— PT ———
WATER LINE	——— W ———

AERIAL UTILITIES: (2" MIN., 4" MAX.)



UNDERGROUND UTILITIES:



1/8" DASHES WITH 1/16" SPACING

FIRE HYDRANT	
INLET	
MANHOLE	
POWER POLE	
POWER POLE WITH GUY	
POWER POLE WITH TRANSFORMERS	2-25-3
VALVE	
WELL - LABEL AS TO TYPE	GAS

TOPOGRAPHY
WORKS AND STRUCTURES

ROADS:

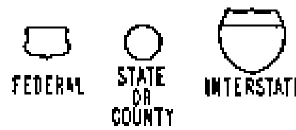
FIELD ROAD OR TRAIL

GRADED DIRT

HAUL ROUTE DESIGNATION

PAVED OR GRAVEL (DESIGNATE MATERIAL)

ROUTE MARKERS



RAILROADS:

SINGLE TRACK

DOUBLE TRACK

ABANDONED

BRIDGES:

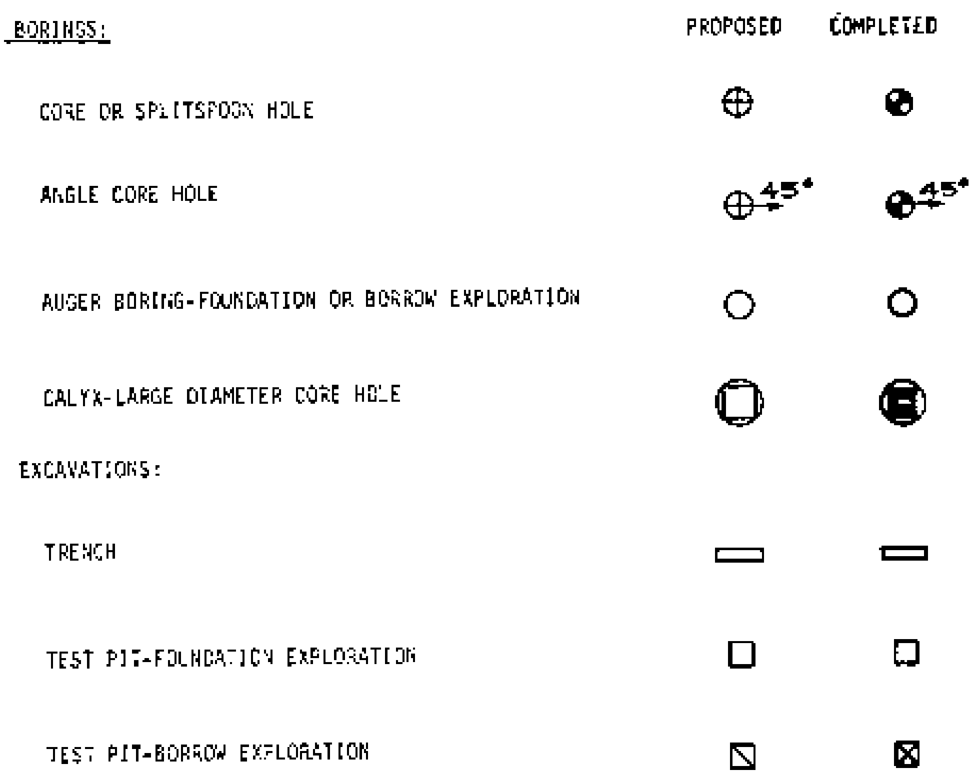
FOOT

FIXED BRIDGE - HIGHWAY

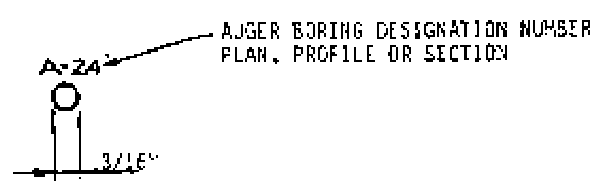
FIXED BRIDGE - RAILROAD

BORROW AREA, STOCK PILE OR SPOIL AREA

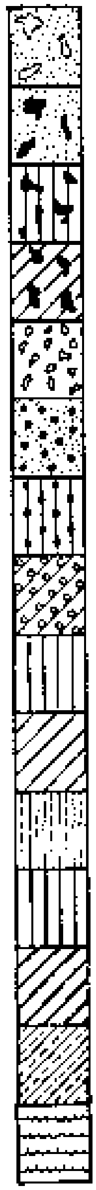
SUBSURFACE EXPLORATION
SYMBOLS



CONVENTION:



SOIL CLASSIFICATION
GRAPHIC LOG SYMBOLS



GROUP SYMBOL	SYMBOL	TYPICAL NAMES
GW		WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
GP		POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
GM		SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES.
GC		CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES.
SW		WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
SP		POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
SM		SILTY SANDS, SAND-SILT MIXTURES.
SC		CLAYEY SANDS, SAND-CLAY MIXTURES.
ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY.
CL		INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS.
OL		ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY.
MH		INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS.
CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS.
OH		ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS.
PT		PEAT AND OTHER HIGHLY ORGANIC SOILS.

HYDROGRAPHIC SYMBOLS
TOPOGRAPHY FEATURES

BANK LINES:

- SURVEYED
- UNSURVEYED

BRIDGES:

- FOOT
- HIGHWAY
- RAILROAD

CONTOURS:

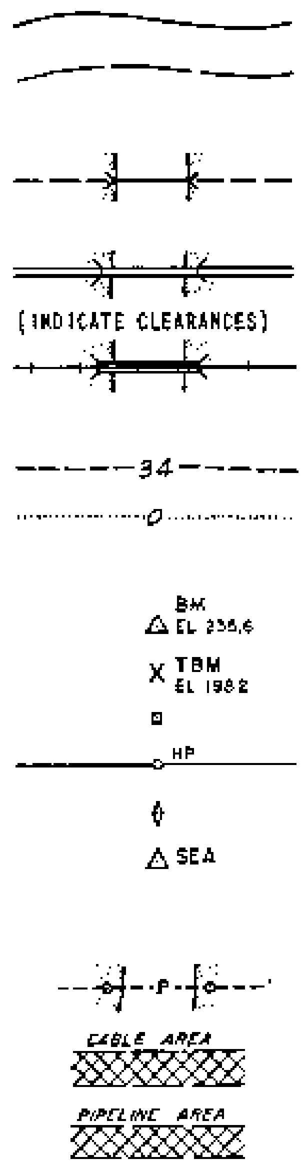
- PROJECT DEPTH
- ZERO

CONTROL POINTS:

- BENCH MARK - PERMANENT
- BENCH MARK - TEMPORARY
- BOUNDARY MONUMENT
- HARBOR LINE
- TARGET
- TRIANGULATION POINT (STATION)

CROSSINGS:

- POWER LINE WITH TOWERS
- SUBMARINE CABLE AREA
- SUBMARINE PIPELINE AREA



HYDROGRAPHIC SYMBOLS
TOPOGRAPHY FEATURES

DAMS:

WITH LOCK

WITHOUT LOCK

DIKES AND RETARDS:

STONE OR PILE DIKE OR GROIN (PARTLY BELOW M.H.W.)

REVETMENTS

MATTRESS TYPE — 1942

(INDICATE DATE CONSTRUCTED)

PILE OR STONE — 1937

JETTY

FLOW DIRECTION — FLOOD EBB FLOW

HAZARDS:

ROCKS

AWASH

UNDERWATER

WRECKS

ANY PART ABOVE WATER

SUNKEN (DANGEROUS TO SURFACE NAVIGATION)

SUNKEN (NOT DANGEROUS TO SURFACE NAVIGATION)

LEVEE OR EARTH DIKE: — PROPOSED EXISTING